KODAK MIN-R

Mammography Screen/Film Systems

Kodak

User Guide

Editors: Anne Richards and Karen Ursel

Purpose and Scope

The following is intended only as a guide for optimizing and maintaining the KODAK MIN-R EV Screen-Film System; site-specific conditions may cause different results. For optimum results, KODAK MIN-R Films, Screens, and Cassettes should be used as part of a system with KODAK processing chemicals and equipment. Although this guide is written primarily for the KODAK MIN-R EV Screen-Film System, much applies to the MIN-R 2000 Screen-Film System. Information pertaining solely to KODAK MIN-R 2000 Film may be found in Chapter 6.

If you have any questions concerning the information contained in this guide, contact your local Kodak representative or contact Health Group Technical Support at ***1-800-328-2910*** *or on Kodak's Health Group internet site:* ***www.kodak.com/go/mammo****. Updates to the information contained in this guide will be posted on the Kodak Web site.*

Contributing Editors: Bill Moore, Bob Dickerson,
Al Fitterman, Jeffrey Byng, Rowen Alberson,
Bill Lipinski, Ron Lillie, Ron Bozek, Marcia Hansen,
Phil Bunch, Lee Ligon, and Dave Steklenski

Using the Guide

The KODAK MIN-R Mammography Screen/Film Systems User Guide includes the following sections to provide information and to help optimize image quality:

Table of Contents:

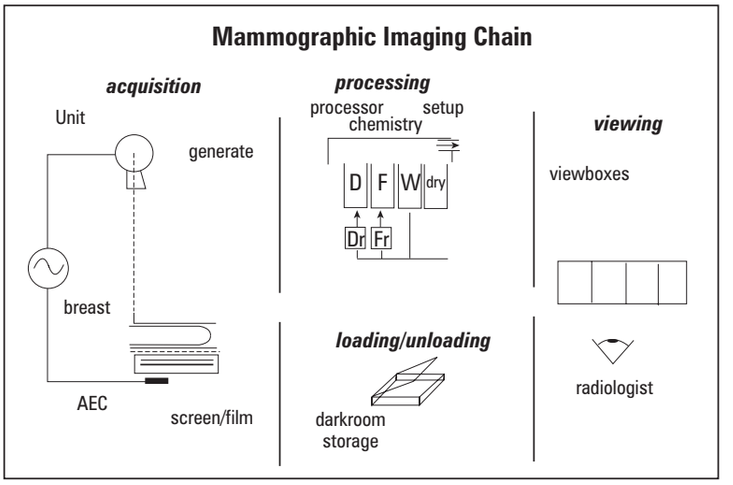
Frequently Asked Questions *page 2*

Chapter One: Introduction—What is the KODAK MIN-R EV Screen-Film System? *page 3*

Chapter Two: Creating and Maintaining a Quality Image *page 8*

1. Darkroom 8
   - Darkroom Considerations
   - Darkroom Fog Test
   - Storage Recommendations
2. Exposing MIN-R EV Film 13
   - Sensitometric exposure
   - Loading the cassette
3. Processing MIN-R EV Film 14
   a. Processors—General Recommendations 16
      - Type of processor
      - Set up
      - Processor Maintenance Procedure
        – Processor Maintenance Form
      - Temperature Effects
      - Immersion Time Effects
      - Monitoring and Maintenance
      - Sample Processing Benchmarking Form

   b. Chemistry 23
      - Proper Mixing and Storage
        – Oxidation
      - Developer
        – A Method for Evaluating Film Performance in Other Manufacturers' Developer Solutions
        – Starter
        – Replenishment
        – Frequency of Changing the Developer Solution
      - Fixer
        – Image Tone
        – Dye Stain
        – Method for Evaluating Film Performance in Other Manufacturers' Fixer Solutions
        – Hypo Retention



   c. Washing and Water 43
   d. Drying 43
4. Screens and Cassettes 46
   - Cleaning Instructions
   - Uniformity of Screen Speed
   - Screen Film Contact

Chapter 3: Optimizing the Exposure *page 53*

1. Introduction 53
2. Radiographic Contrast 56
3. Subject Contrast 56
4. Film Contrast 58
5. Display Contrast 58
6. Film Response Curves 59
7. Optical Density Series 62
8. kVp Series 63
9. Quick Reference Guide 67

Chapter 4: Quality Control (QC) *page 68*

1. Emulsion Number Log 68
2. Processor QC 68

Chapter 5: Troubleshooting *page 75*

1. Overview 75
2. Processor QC 77
3. Trends in QC Charts 78
4. Fixer contamination of the developer 81
5. Artifacts 82
   - Shadow Images
   - Processor Digs
   - Handling Damage
   - Clean up Film
6. Non-uniformity 84
7. Phantom Image Quality 85
   - Troubleshooting Phantom Image Quality
   - Phantom QC and the Split Phantom Test
8. Clinical Image Quality 86
   - Troubleshooting Clinical Image Quality
   - Image Tone
9. Information Needed by Kodak to Facilitate Troubleshooting 93

Chapter 6: MIN-R 2000 Film System *page 96*

1. Processing MIN-R 2000 Film 96
2. Troubleshooting Processor QC Trends 109
3. Conversion and Processing Recommendations for KODAK MIN-R 2000 Film 112
4. Optical Density Range 118

Appendix *page 119*

1. Conversion and Processing Recommendations for KODAK MIN-R EV Film 120
2. Technical Information Bulletin 3111 (sources: Service Bulletin No. 101 and 180) 137
3. Ventilation 140
4. MQSA Equivalency Statement ... 142
5. Forms 144
   a. Screen Speed Uniformity Form

References *page 146*

KODAK MIN-R EV Screen-Film System User Guide

Frequently Asked Questions

The guide is designed to provide comprehensive information about the KODAK MIN-R EV Screen-Film System and provide answers to frequently asked questions.

- Can I use MIN-R EV Film with my present cassettes/screens? (*Chapter One*)
- What happens if I use MIN-R EV Screens with KODAK MIN-R 2000 Film? (*Chapter One*)
- Why is there only one screen if MIN-R EV film is a dual sided emulsion? (*Chapter Two, Section Two Exposing MIN-R EV Film*)
- Do I need to use a dual sided sensitometer? (*Chapter Two Exposing MIN-R EV Film*)
- What happens if I use the rapid cycle? (*Chapter Two*)
- If it is the same system speed as MIN-R 2000 Film and the MIN-R 2000 screen, why do I need to calibrate my unit? (*Chapter Three*)
- What are proper viewing conditions? (*Chapter Three*)
- How much starter is recommended? (*Chapter Two, Processing*)
- Can I use a rhodium filter without degradation of image quality? (*Chapter Three*)
- If it's dual emulsion, how can I tell which emulsion should be in contact with the screen? (*Chapter One, Chapter Two, Exposing MIN-R EV Film*)
- How do I tell which is the primary emulsion? (*Chapter Two, Exposing MIN-R EV Film*)
- Do I need to use the same dryer temperature as I did with MIN-R 2000 Film? (*Chapter Two, Drying*)
- Should I run the film primary emulsion side up or down? (*Appendix – Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film)*
- What is the safelight recommendation for MIN-R EV Film? (*Chapter Two, Darkroom*)
- What is the contrast of MIN-R EV Film (*Chapter One*)
- Why would I want to use a faster screen? (*Chapter One*)
- Why should I use KODAK chemistry? Isn't all chemistry the same? (*Chapter Two, Processing*)
- Why do I need to use so little starter? (*Chapter Two, Starter*)
- My QC numbers are high, should I add water to the developer tank in the processor in the morning? (*Chapter Five, Processor QC*)
- How long should I retain my developer? (*Chapter Two*)
- How do I know what the replenishment rate should be for MIN-R EV film? (*Appendix – Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film)*
- Why is the hypo retention test stain sometimes green? (*Chapter Two, Fixer*)
- Why do I need to vent the processor? (*Chapter Two, Drying*)
- Can MIN-R EV film be processed with other films? (*Appendix – Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film)*
- My MIN-R EV films look warmer (less blue) than before. (*Chapter Two, Fixer, Water Chapter Five*)
- Shouldn't the developer temperature always be 95°F (35°C) if my processor is in the standard cycle? (*Chapter Two, Processing*)
- Should I run MIN-R EV film emulsion side up or down? (*Appendix – Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film)*
- Can I use other manufacturers' screen cleaning products to clean my KODAK MIN-R EV mammography screens? (*Chapter Two, Screens*)
- How do I perform the screen film contact test? (*Chapter Two, Screens*)
- When I perform the screen film contact test there are multiple spots. Is this acceptable? (*Chapter Two, Screens*)
- What optical density is best for MIN-R EV Film? (*Chapter Three*)
- How do I measure gamma? What does it tell me? (*Chapter Three*)
- When should I reset my QC aims? (*Chapter Four*)
- Should I ever need to keep temporary aims past five days? (*Chapter Four*)
- My clinical phantom optical density changes. What is the acceptable variability? (*Chapter Five*)
- What could be causing the trend in my process control charts? (*Chapter Five*)
- My QC numbers are out of limits. Can I add starter to bring them back into limits? (*Chapter Two, Starter and Chapter Five*)
- My clinical images are not optimized but my QC numbers are within limits. What could be wrong? (*Chapter Three*)
- My QC numbers are out of limits, but the quality of my clinical images is acceptable. What should I do? (*Chapter Four*)

Chapter 1: KODAK MIN-R EV Screen-Film System

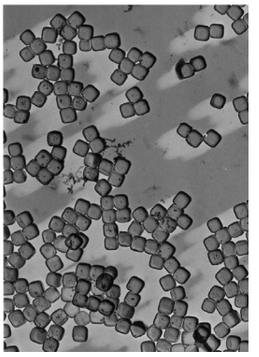
The KODAK MIN-R EV Screen-Film System incorporates innovative design improvements in both the film and the screen. Together with the other components of the KODAK system listed below, they provide significant breakthroughs in performance.

When properly exposed and processed, the KODAK MIN-R EV system will produce the high quality images necessary for interpretation by the radiologist in the detection and characterization of early breast cancer.

MIN-R EV Film

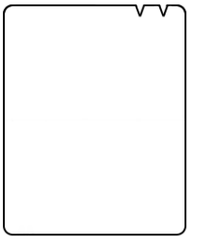
KODAK MIN-R EV Film for mammography is a dual emulsion, high-contrast, orthochromatic (green-sensitive) mammography film to be used with a single screen designed for standard or rapid cycle processing.

- MIN-R EV film has been carefully designed to optimize film contrast throughout the breast while maintaining low overall noise.
- Its optimized contrast yields significantly sharper, more detailed images for detection of very small abnormalities even in dense breast tissue, when compared to previous and current KODAK mammography films.
- Its tolerance for fluctuation in processing temperature and time in solution results in greater consistency for daily QC and image quality.



- MIN-R EV film uses customized silver chloro-bromo-iodide crystals which eliminate neighboring development of silver halide ions, thus decreasing:
  - associated excessive film granularity
  - most forms of processing instability.
- These crystals also create a more blue-black image than other grains.
  - The monodispersed cubic film grains yield high film contrast.
  - The small grain size provides low film noise and high detailed images.

Cubic Film Grains



• KODAK MIN-R EV Film is identified by a spaced double V-notch. The primary emulsion is up when the notches are on the right hand side at the top edge of the film. The primary emulsion should be in contact with the screen during imaging.

KODAK MIN-R EV Film is used with a green emitting terbium-activated gadolinium oxysulfide [Gd_2O_2S:Tb] single-screen. Kodak provides two choices for screens (e.g., KODAK MIN-R EV 150 or MIN-R EV 190 Screens) mounted in KODAK MIN-R 2 Cassettes. Choose the screen according to individual preferences for dose and image quality. Refer to Table 1 and 2. Note that contrast is the same but noise and blur will increase slightly as the dose is reduced.

Table 1: Screen/Film Comparison Chart

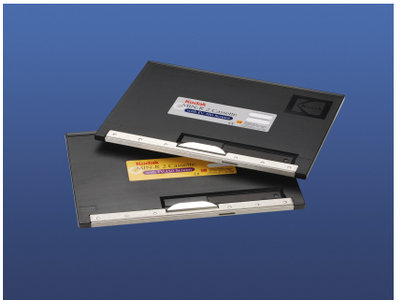
KODAK Film	KODAK Screen	Processing Cycle	Relative Speed[1]	Contrast[2]		D-Max
				RP	EX II	
MIN-R EV	MIN-R EV 150	Standard/ Rapid	150	4.5	4.7	>4.5
MIN-R EV	MIN-R EV 190		190			
MIN-R 2000	MIN-R	Standard	100	3.60	3.80	>4.0
MIN-R 2000	MIN-R 2000		150			
MIN-R 2000	MIN-R 2190		190			
MIN-R L	MIN-R		100	3.40	3.60	>4.0
MIN-R L	MIN-R 2000		150			
MIN-R L	MIN-R 2190		190			
[1] Relative Speed determined from matched-density radiographs of a mammography phantom; KODAK MIN-R M Film and MIN-R Screen arbitrarily assigned a relative speed of 100.						
[2] Contrast—Measured as the average gradient between densities 0.25 and 2.00 above gross fog.						

KODAK MIN-R EV Film is slower than KODAK MIN-R 2000 Film and the MIN-R EV screens are faster than the corresponding MIN-R 2000 and 2190 screens. The combined system results in a similar system speed with improved sharpness. Using MIN-R EV film with other MIN-R screens will result in a lower speed system. Conversely, using MIN-R 2000 film with the MIN-R EV screens will result in films with a higher system speed and possibly increased noise.

KODAK MIN-R EV 150 Screen

The MIN-R EV-150 screen features a number of innovations. The phosphor particle size was reduced compared to the KODAK MIN-R 2000 Screen and the thickness of the screen coating and overcoat was adjusted to increase the screen's brightness. The screen has very low image blur (high MTF) and very high x-ray quantum absorption efficiency.

KODAK MIN-R EV 190 Screen



The MIN-R EV-190 screen is higher [approximately 30%] in speed than the MIN-R EV-150 screen with relatively little increase in image blur. The x-ray quantum absorption efficiency is equal to that of the MIN-R EV-150 screen, i.e. more output at the same exposure. Its faster system speed reduces patient motion-induced image blur, especially important when magnification mammography is performed with longer exposure times.

Table 2: Dose/Image Quality

KODAK Screen	Dose	Noise	Detail
MIN-R EV 150	Low	Lowest	Highest
MIN-R EV 190	Lowest	Low	High

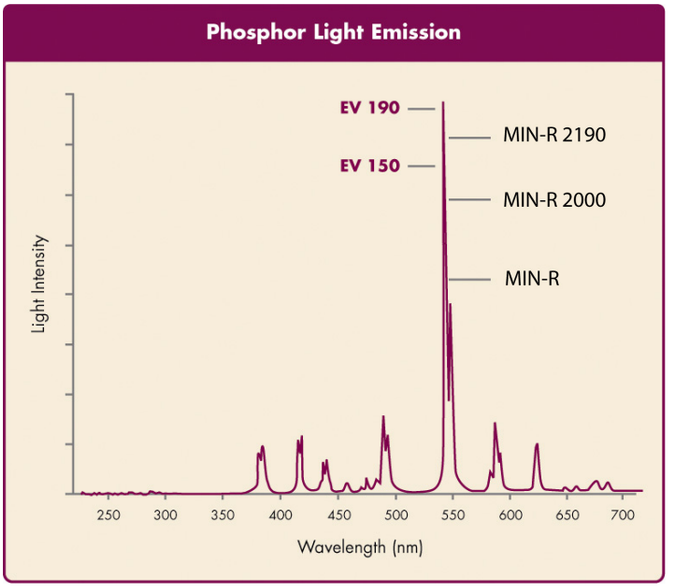


Figure 1: MIN-R EV 190 screen is approximately 30% brighter than MIN-R EV 150 screen and 50% brighter than the older MIN-R screen. For more information, refer to William E. Moore, Robert Dickerson, David Steklenski "Design and performance features of a new mammographic film/screen system" Paper number 54 Proc. SPIE, ***5368****, 2004.*

KODAK X-OMAT EX II Developer and Replenisher

KODAK X-OMAT EX II Developer and Replenisher is a high-quality, non-corrosive, general-purpose diagnostic film developer that is specially formulated to provide highest image contrast and bluest image tone when used as a part of the recommended KODAK MIN-R EV and MIN-R 2000 screen-film systems. It also offers an enhanced viewbox look with many other KODAK films such as KODAK INSIGHT, X-SIGHT and T-MAT films by providing improved visual contrast and image discrimination.

KODAK RP X-OMAT Developer and Replenisher

KODAK RP X-OMAT Developer and Replenisher is Kodak's high-quality most versatile diagnostic film developer. Suitable for standard and rapid cycle processing, this high-performance developer is specially formulated for superb results with films for general radiography, laser imaging, application specific imaging, oncology and mammography.

KODAK RP X-OMAT LO Fixer and Replenisher

KODAK RP X-OMAT LO Fixer and Replenisher is a versatile fixer recommended for all KODAK diagnostic films and other manufacturers' films. It is suitable for standard and rapid cycle processing as well as manual processing. Its special formulation reduces emissions of odor-causing acetic acid and sulfur dioxide to significantly improve processing, mixing, and storage environments.

KODAK RP X-OMAT Developer Starter

KODAK RP X-OMAT Developer Starter was specially formulated for optimal results with KODAK MIN-R EV film and other KODAK medical x-ray films.

Additional information on chemical solutions is contained in the guide (Chapter 2). Please also refer to the KODAK Processing Chemicals Optimization Guide (Cat no. 149 1109, pub number M6-408).

Choose from a complete family of KODAK medical x-ray processors and film-handling equipment suitable for mammography. (Please view the *Conversion and Processing Recommendations for KODAK MIN-R EV Film* in the Appendix for KODAK processors recommended for mammographic applications.) The KODAK MIN-R Mammography Processor and the KODAK Miniloader 2000P are especially suited.

KODAK MIN-R Mammography Processor

The KODAK MIN-R Mammography Processor delivers quality processing in an affordable, compact package. A specially designed film path and dryer improve image quality by substantially reducing the incidence of processing and drying artifacts. The result is increased diagnostic confidence with fewer repeats and more time with patients.

Other Features:

- Automatic standby control turns off the film drive, dryer blower, and dryer heater to save energy when no film is being processed
- Digital developer temperature readout simplifies regulatory record keeping
- When used with KODAK processing chemicals, the KODAK MIN-R mammography processor helps optimize the performance of KODAK mammography films.
  - Standard cycle (rapid cycle configurable)

KODAK Miniloader 2000P

The space-saving KODAK Miniloader 2000 and 2000P automatically load and unload KODAK MIN-R 2 cassettes in full roomlight in just 15 seconds.

Two Configurations:

- The KODAK Miniloader 2000P automatically processes exposed films with an integrated KODAK MIN-R Mammography Processor for maximum processing convenience.
- The KODAK Miniloader 2000, which provides film handling only, has a small footprint and its lightweight receive magazine is ideal for mobile units.

KODAK MIN-R Screen Cleaner

The KODAK MIN-R screen cleaner is specially formulated to optimize the superb image quality of the KODAK MIN-R EV and 2000 Systems. Designed for care of KODAK MIN-R EV 150, MIN-R EV 190, MIN-R 2000, MIN-R 2190, and MIN-R screens, the cleaner helps eliminate dust and dirt that can cause minus density artifacts on the film.

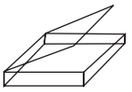
KODAK MIN-R Screen Cleaner Wipes

KODAK MIN-R screen cleaner wipes are convenient, effective tools to help keep KODAK MIN-R screens and cassettes free of dust and dirt that can cause minus-density artifacts on film. The lint-free wipes are pre-moistened with KODAK MIN-R screen cleaner. The lint-free wipes significantly reduce concerns about artifacts caused by lint deposited on screens by cleaning cloths. A measured amount of screen cleaner in every wipe guards against screen staining or damage due to the application of too much cleaner.

Chapter 2: Creating and Maintaining a Quality Image

1. Darkroom: Features and Best Practices

Loading/Unloading



Darkroom
Handling (digs and scratches, contact)
Cleanliness (dust and dirt)
Fog (safelight wattage and distance, lighttight)

Storage
(chemistry and film)
Temp, water, humidity
Stock rotation

Features and considerations:

Ceilings

Darkroom ceilings should be solid, if possible, smoothly finished and painted.

If the darkroom is old (i.e., constructed many years ago), check all materials used in the ceiling, i.e., paint, for brittleness and replace, if necessary.

Suspended Ceilings

- Can be a significant source of dirt and dust.
- Door closing may cause dust to sift down from the tiles and dead space above the ceiling.
- If no access is needed to the area above the ceiling, seal the tiles to the suspension frame to prevent ceiling tile movement when the darkroom door is closed.
- Seal the surface and edges of the ceiling tiles themselves to decrease/eliminate airborne particles from the tiles; check with the ceiling tile manufacturer for an appropriate sealant (e.g., semi-gloss paint or polyurethane) and with local authorities to ensure that sealing the tiles in any manner does not violate local fire codes.
- If you must use a suspended ceiling, consider securely taping a large continuous sheet of plastic over the ceiling to contain the dust. If access to the area above the suspended ceiling is required, it could easily be removed.

Doors

- Install a revolving (barrel-type) door to eliminate door slamming/dust sifting down from the ceiling and to improve traffic flow into and out of the darkroom.
- Check the felt installed as part of revolving doors as it may be an additional source of lint.
- Locate ventilation louvers in darkroom doors near eye level, not near the floor, and vacuum or wipe periodically.

Darkroom

- Darkroom should be light-tight.
- Insure that the venting meets Kodak's site specification recommendations. (See Technical Information Bulletin No. 3111 in the Appendix.)
- Darkroom walls should be smoothly finished, painted using a light-colored semi-gloss paint, and clean.
- Walls painted with semi-gloss paint are easier to keep clean.
- The use of a light-colored paint maximizes safelight illumination and makes it easier to work in the darkroom.
- **The use of black paint is not recommended.**
- Avoid flat paint because dust can cling more easily to walls and they are difficult to wash.
- Scrape and repaint walls that have peeling paint.
- Replace any open shelving.
  - No open shelving of any kind should be used, especially above darkroom countertops.
  - **If storage is needed in the darkroom, cabinet doors must be installed.**

Example of an ideal darkroom
Courtesy of Elizabeth Wende Breast Clinic, Rochester, NY

Points to consider when there is new construction

- **Contain dust in or near the darkroom**
- **Avoid drywall dust accumulation in vent pipes or long-term dust/shadow image problems may result on mammograms**
- **Avoid installing any new equipment such as a room light processor, in an area still under construction.**

Tips

- A relative humidity (RH) of between 30 and 50 percent must be maintained to minimize the attraction of dust and dirt onto films and intensifying screens.
- Filter air coming into the darkroom, either at the system level, or by placing furnace-type or HEPA filters in the air vents feeding the darkroom.
- Change air filters according to the frequency recommendations of the manufacturer.
- Electrostatic air cleaning devices may be helpful if a significant dust problem exists in the darkroom.

10 room air exchanges per hour are recommended for a room that is 10 x 10 x 10 feet.

- Only use a vacuum cleaner in the darkroom if the dust particles that could be stirred up from the vacuum exhaust have enough time to settle (e.g., overnight). Then clean the countertops, floors, and film feed tray.
- Wet mopping is recommended.
- Thoroughly clean vents on a regular basis.
- Minimize storage in the darkroom.
- Open cases of film and other corrugated cardboard boxes outside the darkroom.
- New boxes of film should be opened slowly and carefully to reduce cardboard fibers from becoming airborne.
- If film is stored in a film bin, remove the flap, stiffener boards and box top from the darkroom after placing the film (in its envelope and box, to ensure no movement) in the film bin.
- Remove the stiffener cardboard from film boxes if the film is stored in the box. Do not leave the stiffener boards in the darkroom.
- Use a pair of scissors to cut the envelope to reduce airborne fibers.
- Do not store loose film in the box, film bin, or film safe at any time.
- Avoid replacing unexposed film that has been inside a cassette back into the film supply.
- Switch from an identification (ID) printer or camera located in the darkroom to a camera located outside or to an ID-capable mammography unit to eliminate fibers from the thin paper cards inserted into the printer or camera in the darkroom. If using an ID printer or camera, remember to clean it on a regular basis.
- Eliminate non-essential items that contribute to dust and paper fiber.
- Require all darkroom personnel and technologists to wear lint-free clothing or to wear smocks or lab coats over clothing.

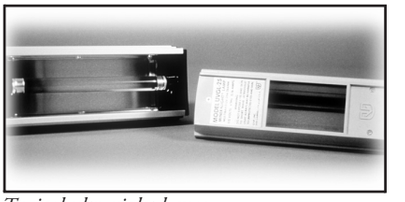
If cassettes and screen must be cleaned more than once a day and all of the above have been implemented, investigate air changes and venting.

Troubleshooting the Darkroom

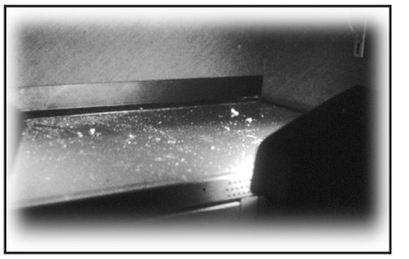
The following suggestions are intended to help reduce airborne dust, dirt, and lint from the environment, and make the darkroom easier to keep clean:

Before Cleaning

- Use an ultraviolet, or black, light to identify sources of dust and dirt in the darkroom.
  - Note that all dust particles do not fluoresce under ultraviolet illumination.
  - Limit exposure prudently and observe appropriate safety precautions for eyes, face, and exposed skin; do not look directly at the light.
  - Do not expose film to ultraviolet light.
  - Use the light again after cleaning.



Typical ultraviolet lamps
Be sure to follow the UV light manufacturer's instructions to ensure safe handling of the UV light



Dust and dirt on processor feed tray. Left undisturbed, they will lead to artifacts on film.

Perform daily:

- Damp mop darkroom floors.
- Clean darkroom countertops using a lint-free wipe and appropriate non-residue cleaner.
- Clean the processor film feed tray last.
  - Use a KODAK MIN-R screen cleaner wipe or moisten a lint-free wipe with a small amount of KODAK MIN-R Screen Cleaner used for intensifying screens.
  - If the feed tray needs to be cleaned more frequently, use the ultraviolet light to check the cleanliness of the incoming air.

Perform weekly or as needed:

- Wipe darkroom walls, the fronts of cabinets, safelights, vent surfaces, exposed pipes, etc., with a damp lint-free wipe periodically to eliminate clinging dust.
- If passboxes are used, check the insides for paint particles, metal flakes, dust etc.

Clean monthly.

- Clean the ID Camera.
  - the Model 1 ID camera should be cleaned monthly or more frequently if fibers are noted
  - the counter it sits on should be cleaned daily.
- Vacuum or use a damp lint-free wipe to remove dirt and dust from the inside of the film bin occasionally (e.g., once a year, or as needed).

Adjust frequency of occasional cleaning as warranted by the frequency of minus density artifacts. Typically they should be performed weekly.

Miniloaders/Multiloaders

Perform Weekly:

- Clean supply magazines using a damp lint free cloth

Monthly or as needed (minimum quarterly):

- A qualified service person should vacuum the mini/multiloader supply magazines using a recommended service vacuum or attachment used to clean computer so as not to introduce static.
- Vacuum the cassette area with the special vacuum.
- If the anti-dust modification has been installed on the Miniloader 2000, the filter inside the cassette area opposite the fan should be removed during the PM and cleaned.
- Power Supplies, and some electrical drawers may collect dust. These areas along with the filters should be vacuumed, and any filters cleaned.

Darkroom Fog

Perform Quarterly

- Close the door and turn off the lights. Note any light leaks and take corrective action to eliminate them. Sometimes fog arises from exposure to light other than from safelights. Sources to consider are light leaks around doors, cracks in walls, or cracks where ceiling partitions join walls.

The Darkroom Fog Test

Safelight fog in a darkroom can affect film consistency and overall contrast. To determine if safelight fog is present, you must perform the darkroom fog test. This test should be performed after evaluating and eliminating any obvious light leaks. The darkroom fog (safelight) test should be performed at least semi-annually. Several factors can affect test results.

Tools

- Mammographic x-ray unit
- Phantom
- Mammography Cassette
- MIN-R EV Film
- Mask /cardboard (must be opaque)
- Stopwatch or timing device
- Densitometer

Procedure

- Turn off safelight(s)
- Load the film into the cassette in total darkness.
- Expose the film and cassette to the appropriate optical density

> Expose the film using the same protocol as the phantom test. Adhering to this density range is especially important for high-contrast mammography films such as KODAK MIN-R EV Film.

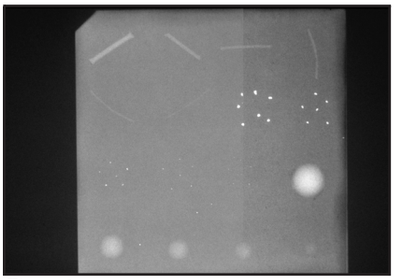


Figure 1

- With safelights still off, remove the exposed film.
- Place on counter primary emulsion side up (the notch should be on the upper right).
- Cover one-half of the phantom image with the mask.
- Turn on safelights.
- Wait two minutes.
- Remove mask.
- Process film.

- Using the densitometer, measure the optical density of the fogged (exposed to safelight) and masked areas.
- Calculate the difference in optical density.

Performance Criteria

The difference in optical density should not exceed 0.05.

Troubleshooting

- **Use the appropriate safelight filter.**

  A KODAK GBX-2 Safelight Filter, or equivalent, is the correct safelight filter for all KODAK Mammography Films.

- **Change the safelight filter periodically.**

  Safelight filters can fade and crack with age. Heat from incandescent bulbs can crack safelight filters over time.

- **Install the safelight filter correctly.**

  Filters should be installed so that the identification printing can be read when looking at the lamp. If the filter orientation is reversed, excessive heat buildup inside the lamp housing may cause the dye layer to crack and thus leak unsafe light.

- **Use the appropriate wattage bulb.**

  Oversized bulbs can damage the safelight filter from excessive heat. A 7.5 watt incandescent bulb is recommended for all KODAK Mammography Films.

- **The distance** of the safelight from the work surface and the direction of the light to the work surface can affect results. Also consider directing the safelight toward the ceiling.

- **Use the appropriate number of safelights for the size of your darkroom.**

  In large rooms with white ceilings, place no more than one lamp for every 64 square feet (6 square meters) of ceiling area.

- **Other sources of fog.**

  Automated processors will vibrate sufficiently to cause small openings between the light seals and the adjoining partition or the processor cover may not be tightly closed. Afterglow from some types of fluorescent lights can cause fogging. Glowing lights or dials on equipment located in the darkroom can fog film.

If using a LED safelight, such as the KODAK LED Safelight, the safelight must be installed in the ceiling and pointed away from the work area.

Storage Recommendations

Storage of Unprocessed/Unexposed Film

Most medical x-ray films come in a sealed, moisture-proof inner wrap, which is packed in an outer cardboard box. Sealed packages of film are affected by heat; open packages are affected by both heat and to a lesser extent humidity.

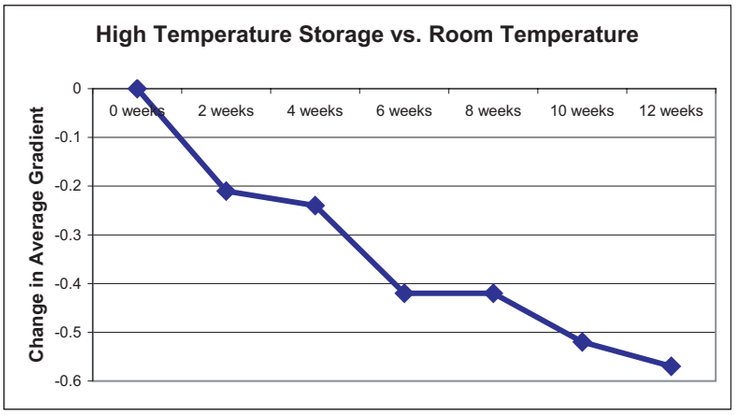
All packages of Kodak film should be stored away from heat sources: store in a cool, dry place at a temperature between 50° and 75°F (10° to 24°C). The National Council on Radiation Protection and Measurements (NCRP) Report No. 99 recommends that photographic material be stored at temperatures less than 75°F (24°C).

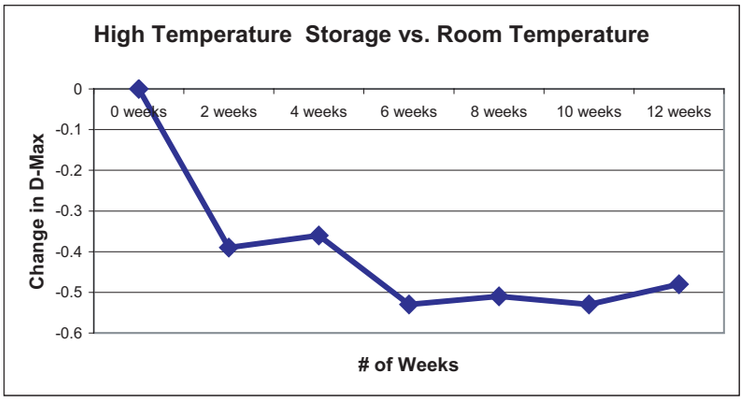
For consistent results, allow film and cassettes stored below the recommended temperature to return to between 65° and 75°F (18.3° to 24°C) before use.

The film should be exposed and processed at room temperature (65-75°F/18.3° to 24°C). In general, the film may gain speed and lose contrast if used at colder temperatures and may lose speed and gain contrast if used at higher temperatures (closer to 75°F/24°C). Storing film for a prolonged period of time at temperatures higher than 75°F (24°C) may result in an increase in speed and decreased contrast and D-Max.

NOTE: *Storing films outside of these temperature [50-75°F (10° to 24°C)] and relative humidity (30-50% RH) values can affect the sensitometric qualities of the film. Storing at colder temperatures will not adversely affect the film as long as it is allowed to come to room temperature before use. Storing unexposed film at temperatures higher than 75°F (24°C) may cause a decrease in contrast and D-Max.*

The charts below illustrate the changes in average gradient and D-Max over time between film stored at room temperature and high temperature [100°F (37.8°C)].





Keep open packages of film at a consistent relative humidity (RH) between 30 and 50 percent. An inexpensive instrument called a sling psychrometer can be used to measure relative humidity. This instrument is commonly available through precision instrument supply houses. Hygrometers may also be used to measure relative humidity. Check the accuracy of the instrument under consideration before purchasing it.

Temperature and relative humidity values frequently fluctuate throughout medical facilities from season to season. Year-round tight control of temperature and relative humidity should be the goal to achieve and maintain high quality and stable radiographic images.

Store films

- Away from chemical fumes and radiation
- On edge (like books in a library)
- Stacking horizontally may show pressure artifacts.
- Rotate films on a first in first out basis.

Storage of Processed Film

Proper storage and handling of processed film is imperative for stability of the radiographic image. It is especially important to treat single-emulsion mammography film with great care, the same care you would give to your most treasured family photographs.

Film must be thoroughly washed during processing to remove residual fixer, which can cause staining and fading. Tests for fixer retention should be done at least every three months. Refer to the Hypo Retention section (Chapter Two) for further information on performing this very important test.

Since all films contain gelatin as one of the principal ingredients of their emulsion, it is important to maintain a constant temperature at about 70°F (21°C) and 40 to 60 percent relative humidity.

Low humidity and high temperature can cause emulsion cracking, an artifact that appears as a series of fine parallel or spider-like lines in a D-max area of the film. To reduce the propensity and/or avoid cracking:

- Store at the constant recommended temperature
- Limit hot light exposure time
- Have proper wattage for hot lights.

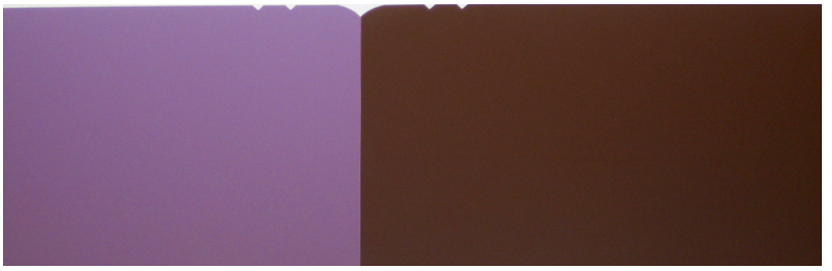
Example of Emulsion Cracking, courtesy Kodak Colorado Microsopy Laboratory

2. Exposing MIN-R EV Film

MIN-R EV film has the look and feel of a single emulsion mammography film. The film has a spaced double V notch. The primary emulsion is up when the notch is on the right hand side at the top edge of the film. When orienting the QC film for the sensitometric exposure, the primary emulsion side of the film should be oriented primary emulsion side down.

The sensitometer should be set to single/green exposure.

The primary emulsion is also the emulsion that is placed next to the screen in the cassette and images the breast tissue, therefore the film is loaded in a mammography cassette the same way single emulsion mammography film is loaded.



L. Primary emulsion
(notch in upper right corner)

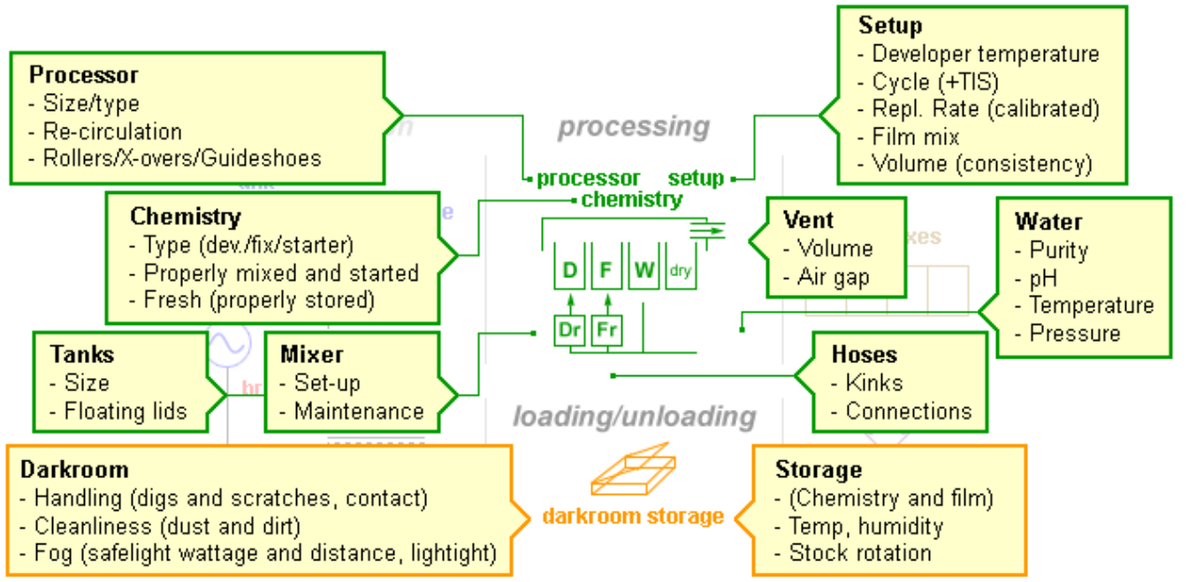
R. Secondary emulsion
(notch in upper left corner)

The primary emulsion appears flat (dull) while the secondary emulsion has been given a shinier, browner appearance.

The primary emulsion images the breast parenchyma up to an optical density of 3.0. The backside (secondary) emulsion crosses over to image the upper density and D-Max. The emulsions are different speed and composition so no interactions will occur.

Note that the B+Fog of KODAK MIN-R EV Film may be slightly higher than that of MIN-R 2000 Film due to the higher level of blue support used.

3. Processing MIN-R EV Film



A. Processors—General Recommendations

- Type of processor
- Set up
- Temperature Effects
- Immersion Time Effects
- Monitoring and Maintenance
- Sample Processing Benchmarking Form

B. Chemistry

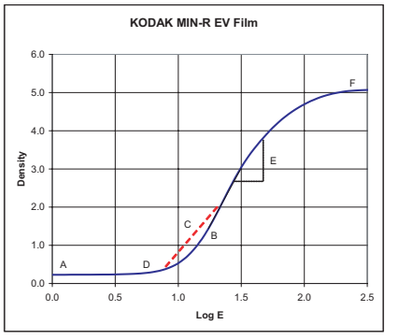
- Proper Mixing and Storage
  - Oxidation
- Type of Chemistry
- Developer
  - A Method for Evaluating Film Performance in Other Manufacturers' Developer Solutions
  - Starter
  - Replenishment
  - Frequency of changing developer solution
- Fixer Considerations
  - Image Tone
  - Dye Stain
  - Method for Evaluating Film Performance in Other Manufacturers' Fixer Solutions
  - Hypo Retention

C. Washing and Water

D. Drying

Throughout this guide we will be relating changes in daily process control numbers caused by: the type of processor, inappropriate time in solutions, developer temperature, oxidation and over or under replenishment, to possible effects on the sensitometric curve and the clinical image.

Please note that the sensitometric data contained in this guide is applicable only when using KODAK MIN-R EV Film with properly mixed solutions of KODAK chemistries recommended for mammography. If using another manufacturer's chemistry, it is recommended that similar information be requested from that manufacturer. Information pertaining to KODAK MIN-R 2000 Film may be found in Chapter 6.

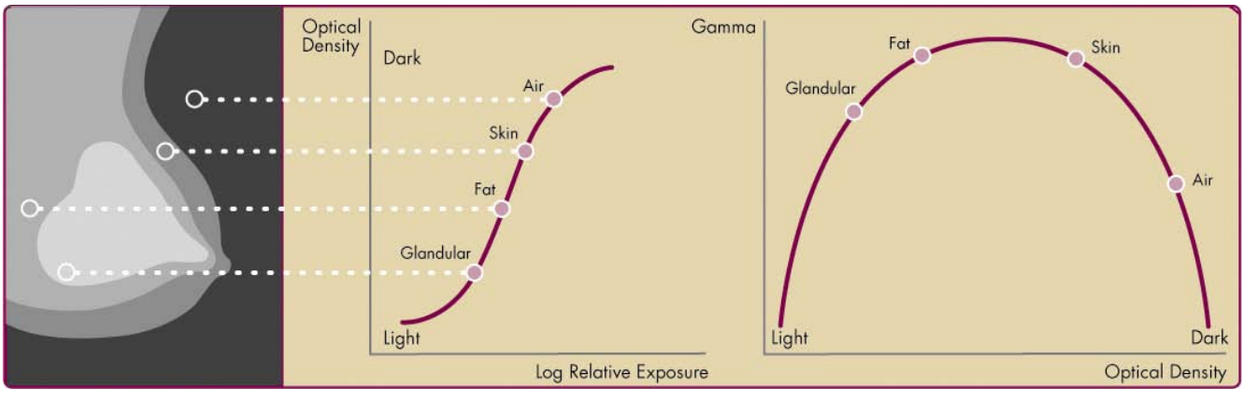


Sensitometric Curve KODAK MIN-R EV Film processed in KODAK X-OMAT EX II Developer and KODAK RP X-OMAT LO Fixer in a KODAK X-OMAT 480 RA Processor.

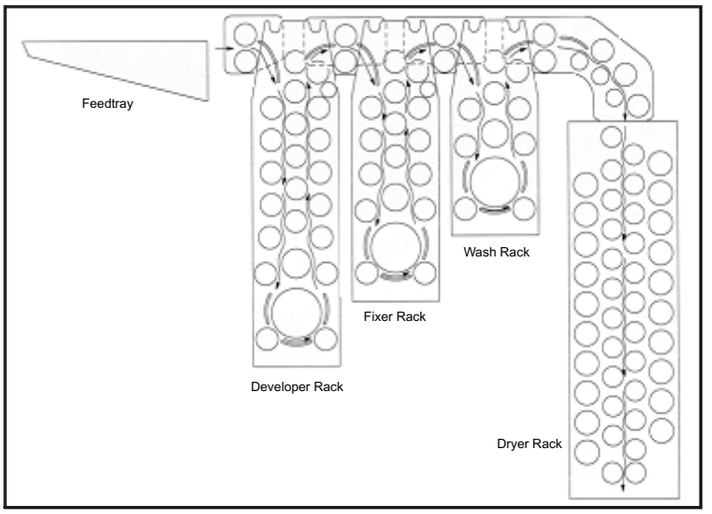
Legend

A = B+ Fog
B = Speed
C = Mid-scale Contrast or Average Gradient
D = Toe (Whites)
E = Shoulder Contrast
F = D-Max

Changes in these parameters: B+Fog, Speed, Mid-scale Contrast, Toe, Shoulder Contrast and D-Max can directly affect the clinical image as illustrated in the chart below. It is important to validate changes in sensitometry or process control to the phantom or clinical image.



A. Processors—General Recommendations:



For optimal results, it is important to:

- Select the appropriate processor
- Properly set up the processor for MIN-R EV film.
- Properly maintain and monitor the processor.

Processor Recommendations

The size of the developer and fixer tanks as well as the roller configurations can affect the performance of mammography film as illustrated in the table below for KODAK MIN-R EV Film.

	Large Tank (5000 RA, 480 RA, 460 RA, M6B)	Medium Tank (MIN-R Mammography, 3000 RA, 270 RA, M35M)	Shallow Tank (X-OMAT 1000, Medical X-Ray)
Mid-Density measured at 1.0 above B+Fog (Speed Index)	=	"="	↑½
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	=	"="	↓ ½
D-Max	=	"="	↓↓
Image Tone	=	"="	↓↓↓↓
Artifacts	=	"=" (processed primary emulsion side down) ↑↑plus density artifacts processed primary emulsion side up	↑↑↑↑
KODAK X-OMAT EX II Developer / KODAK RP X-OMAT LO Fixer			

	Large Tank (5000 RA, 480 RA, 460 RA, M6B)	Medium Tank (MIN-R Mammography, 3000 RA, 270 RA, M35M)	Shallow Tank (X-OMAT 1000, Medical X-Ray)
Mid-Density measured at 1.0 above B+Fog (Speed Index)	=	"="	↑
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	=	"="	↓
D-Max	=	"="	↓↓↓
Image Tone	=	"="	↓↓↓
Artifacts	=	"=" processed primary emulsion side down, ↑↑ plus density artifacts processed primary emulsion side up	↑↑↑↑
KODAK RP X-OMAT Developer / KODAK RP X-OMAT LO Fixer			

For this comparison the deep tank processor category is the baseline.
"=" is equivalent.

Mid-Density: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient.

D-Max: ↑ is 0.10 change in optical density.

↑ Increased Level of plus density artifacts.

Optimal or similar image quality will not be achieved in shallow tank processors.

Set Up

Ensure that the processor is installed as per the processor manufacturer's site specifications. Site specifications for many KODAK processors may be found on the Health Imaging website at

http://www.kodak.com/global/en/service/nav/medicalProcessors.jhtml.

Ensure that the processor and dark room ventilation are set up as per recommendations.

Ensure that the processor is set up as per Service Bulletin No. 30 for processing cycle, immersion time, developer and fixer temperatures and replenishment rates.

Drain, clean and flush the developer and fixer tanks.

Change the filters.

Refill the processor with properly mixed KODAK chemistry using the appropriate amount of KODAK RP X-OMAT Developer Starter.

Developer Processing Time and Temperature

- KODAK MIN-R EV Film should be processed using the standard or rapid processing cycles (if using KODAK X-OMAT EX II or RP X-OMAT Developers with KODAK RP X-OMAT LO Fixer); developer immersion time and developer temperature should be as specified by the processor manufacturer as equivalent to a standard or rapid cycle.
  - Note that the contrast will not increase if extended cycle processing is employed.
  - The table below reflects standard and rapid cycle processing parameters for KODAK X-OMAT Processors; for other brands of processors, check with the manufacturer to ensure use of a standard cycle.

KODAK X-OMAT Processor(s)	Developer Immersion Time (Approximate)	Developer Temperature
MIN-R Mammography	33 seconds (Standard) 25 seconds (Rapid)	92°F (33.5°C) (Standard) 94°F (34.4°C) (Rapid)*
M35M and M35A-M	33 seconds	92°F (33.5°C)
M7[1] and M7A[1]	31 seconds	92°F (33.5°C)
270 RA, 3000 RA; XML 300, XML 300 Plus, XML 7000	27 seconds (Standard) 19 seconds (Rapid)	94°F (34.4°C) 99°F (37.2°C)
M7[2]. M7A[2]. M7B	26 seconds	94°F (34.4°C)
460 RA, 480 RA and 5000 RA	24 seconds (Standard) 16 seconds (Rapid)	95°F (35°C) 101°F (38.3°C)(Rapid)
M6B, M6-N, M6A-N, M6AW, M6R	25 seconds	95°F (35°C)
M8	21 seconds	96°F (35/6°C)
[1] KODAK X-OMAT M7 and M7A Processors with 140-second total processing time		
[2] KODAK X-OMAT M7 and M7A Processors with 122-second total processing time		

*The cycle time should be set by qualified service personnel.

How Different Processing Times Affect MIN-R EV Film

The contrast, toe and D-Max of KODAK MIN-R EV Film are relatively insensitive to small changes in developer time and temperature.

Sensitometric Parameter	Transport Speed (inches/minute)		
	34 inches/min (Ext'd Cycle)	66 inches/min (Standard Cycle)	99 inches/min (Rapid Cycle)
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↑↑↑↑↑↑↑↑	"="	↓↓↓
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	"="	"="	↓
Toe Contrast (Whites)	↓	=	=
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↓½	=	↓↓↓
D-Max (Darkest)	"="	=	↓
Drying	↑	=	"="

Testing was performed in a KODAK X-OMAT 5000 RA Processor with a developer temperature of 95°F (35°C).

Baseline is standard cycle.

NOTE: The Standard and Rapid cycle give equivalent sensitometric results when the recommended developer temperature is used.

"=" is equivalent to the baseline

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder Contrast: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density

Drying: ↑ is improved, ↓ is worse

Developer Temperature Sensitivity

As is illustrated in the chart below, the contrast of MIN-R EV film decreases slightly with lower and higher temperatures.

Sensitometric Parameter	Developer Temperature		
	91°F (32.8°C)	95°F (35°C)	99°F (37.2°C)
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↓↓↓↓↓	=	↑↑↑↑↑↑↑
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	↓↓	=	↓
Toe Contrast (whites)	=	=	"="
Shoulder Contrast ↑Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑↑↑↑	=	↓↓↓
D-Max (darkest)	½↓	=	=

Processed in a KODAK X-OMAT 480 RA Processor

95°F (35°C), as recommended for the KODAK X-OMAT 480 RA Processor, is the baseline for comparison.

Mid-Density: ↑ is 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder Contrast: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density.

Please note that similar results would be seen in other processors varying plus or minus four degrees from the processor manufacturer's recommended developer temperature for the standard cycle. It is therefore important to follow the manufacturer's recommendations for developer temperature.

Monitoring and Maintenance

To monitor that the processor is consistent, quality control (sensitometry) must be performed.

For best results, be sure to follow a regular preventive maintenance schedule. It may be beneficial to keep a processor maintenance log with your quality control log.

Processor Benchmarking Form **Date:** 11/25/2003

Film Used: *MIN-R EV*
Dedicated Mammo processor (Y) ***N***
Film type:_____Mix (% of mammo vs. other film): _____
Film Volume per Day_____Single Feed (Double Feed)
Any change in volume noted or expected since last visit? (Y) ***N***
Emulsion log kept: (Y) ***N***
Chemistry, Mixing: (specify ***KODAK / KODAK repack / OM***)
Developer Type: *KODAK EX II*
Automixer Used: (Y) ***N*** Type: *100-K* Date of last PM: *11/25/03*
Specific Gravity at 70F Developer *1.076* Fixer *1.09*
Premix
Delivery schedule:_____
Date replenishment tanks cleaned _____
Dev. Replenisher Tank Volume: _____ floating lid in place?_____
Date floating lids last cleaned _____
Dev. Starter in Processor: (Y) ***N*** Volume in tank: _____
Fixer Type: *KODAK RP LO*
Fix Replenisher Tank Volume _____ Volume in tank:_____
Silver Recovery: ***Y N*** Model: _____
Fixer recycled: ***Y N***
Processor
Manufacturer and model: *Kodak MIN-R Mammo* Cycle: _____
Date of Last processor PM: *10/12/03* Date of last processor cleaning: _____
Mods Installed: _____
Mods Needed: _____
Processor Schedule: S (M T W T F) S (circle all that apply)
Dev. Temp: *92* Fixer Temp: Calibrated thermometer ***Y N***
Is developer temperature set as per Service Bulletin No. 30? ***Y N***
If not, explain why: _____
Replenishment
Replenishment Rate DEV:*50* Verify: overflow? ***Y N*** Validate: tubes/hoses OK (Y) ***N***
Replenishment Rate FIX:*60* Verify: overflow? ***Y N*** Validate: tubes/hoses OK (Y) ***N***
Are rates set as per Service Bulletin No. 30? (Y) ***N***
If not, explain why: _____
Fixer Retention: Date last performed: *7/1/03* Results: *Patch 2*
Special Conditions (e.g. smart replenishment): (Y) ***N*** Explain:_____
Proper software installed: ***Y N*** Explain:_____
Date Replenishment last calibrated: *11/25/03*
Date developer was last changed: *10/12/0*3
Date of last fresh Start: *10/12/03* next scheduled *12/12/03*
Date of last developer filter change: *10/12/03*
Wash
Wash water temp: *70* Date of last water filter change: *7/1/03*
Dryer Temp: *130*
Venting
Venting checked: (Y) ***N*** OK: (Y) ***N*** Air Gap Correct: (Y) ***N***
Humidifier present : ***Y*** (N) Model: _____
Water
Mixing Valve: (Y) ***N***
Incoming temperature: *70*

© Eastman Kodak Company 2002

Periodic Maintenance (PM) Procedure for Kodak X-OMAT and MIN-R Mammography Processors

1. Question the operator regarding any recent problems.
2. Inspect the processor for any obvious signs of leakage.
3. Process 4 test films: 1 D-Min, 1 D-Max, 1 1.5 Neutral Density and a control strip.
   a. Use the customer's equipment.
   b. Inspect for artifacts.
   c. Save these films to compare with those you will process after the PM.
4. Complete the Periodic Maintenance procedures as detailed in the Periodic Maintenance Checklist:
   a. De-energize the processor.
   b. Remove the crossovers, evaporation covers.
   c. Remove the developer and fixer working solutions from the tanks.
   d. Drain the wash tank.
   e. Rinse the tanks with water; rinse racks prior to removing.
   f. Remove the developer filter and discard. The recommended replacement frequency is 1 month or after 5000 sheets of film are processed.
   g. Remove the racks (use drip trays).
   h. Close the drain valves, and fill the tanks with tepid water. Energize the processor.
   i. Clean and inspect the racks and crossovers:
      1. Rinse the racks and crossovers with warm water, and clean them with a soft cloth or sponge (no abrasive scouring pads).
      2. Inspect the rack components on each rack for wear, rust, or damage. The inner and outer path rollers and turnarounds should be examined. If necessary, replace the worn and damaged parts.
      3. Adjust the chain tension, if necessary.
   j. Install the racks and crossovers into the processor.
   k. Fill the tanks with water, and energize the processor. While the transport is operating, look and listen for any obvious problems with racks, main drive or dryer belt and pulley.
   l. Adjust the dryer belt tension and tracking, if necessary.
   m. Adjust the alignment and the tension of the main drive chain, if necessary.
   n. Inspect all plumbing for leaks, etc.
   o. Remove the dryer air tubes and rollers. Clean, inspect and replace them, if necessary.
   p. De-energize the processor.
   q. Clean chemical deposits from all surfaces.
   r. Drain water from all tanks.
5. Install a new developer filter and check strainers.
6. Check the Dryer exhaust ventilation when processor is de-energized for proper flow rate.
7. Fill the processor with appropriate chemistry.
   - Add the appropriate amount of KODAK RP X-OMAT Developer Starter to the developer tank as the developer tank is being filled.
8. Energize the processor.
9. Calibrate the replenishment pumps.
10. Process 4 films: 1 D-Min, 1 D-Max, 1 1.5 Neutral Density, and a control strip.
    - Use the customer's equipment.
    - Inspect for artifacts.
    - Compare these films with those processed before the PM to ensure that no artifacts or other problems were introduced during the PM procedure.

11. Explain to the operator how any problems were corrected.
12. Have the operator process film.
13. Be sure the operator is satisfied with the processor operation.
14. Complete the Periodic Maintenance Checklist and the Distributor Worksheet and leave with a copy of the signed work order.

KODAK X-OMAT and MIN-R Mammography Processor

Periodic Maintenance Checklist

Customer Name:_____Model: _____K#: _____

- ☐ Remove Dev/Fix working solutions from tanks
- ☐ Check floor drain for flooding
- ☐ Clean all crossover assemblies
- ☐ Check rollers, gears, bearings for wear and broken parts
- ☐ Refer to parts list below for parts replaced
- ☐ Clean wash rack and exit squeegee rollers
- ☐ Clean developer, fixer and wash tanks
- ☐ Clean main drive trough
- ☐ Clean filter housing and threads
- ☐ Clean developer rack
- ☐ Clean fixer rack
- ☐ Check racks for rubber delamination, cracks, loose sprockets, gudgeons, bound spacers
- ☐ Clean guide shoes
- ☐ Clean holes in spray bars (if applicable)
- ☐ Check and adjust chain tension
- ☐ Check racks for squareness
- ☐ Clean accumulator assembly (if applicable)
- ☐ Install new developer filter
- ☐ Fill tanks with new chemistry
- ☐ Add recommended amount of developer starter
- ☐ Check operation of area accumulator (if required)
- ☐ Check recirculation system for proper operation
- ☐ Clean dryer tubes, rollers and sideplates
- ☐ Check or replace o-rings
- ☐ Check dryer drive belt for wear
- ☐ Check main drive chain for wear
- ☐ Lubricate main drive chain
- ☐ Clean around pumps and motors
- ☐ Clean replenishment strainers
- ☐ Check fixer replenishment rate
- ☐ Check developer replenishment rate
- ☐ Calibrate replenishment pumps (if applicable)
- ☐ Check dryer set point
- ☐ Check processor air exhaust ventilation
- ☐ Check film for artifacts

Parts Replaced			
Part #	Description	Part #	Description

Notes and Comments:

_____

_____

_____

Fill out the distributor processor benchmarking form.

B. Chemistry

Chemistry Formats and Mixing Considerations

Concentrate

Manual Mix

Water Temperature and Quality
Mixing Order
Dilution
Oxidation
Volume Mixed
Agitation

Automixer

Water Temperature and Quality
Mixing Order
Dilution (Consistent)
Oxidation

Bulk Mix or Pre-Mix

Water Temperature and Quality
Mixing Order
Dilution
Agitation
Oxidation
Age of Mixed Solutions
Storage of Mixed Solutions

General Steps for Manual Mixing

Developer and Fixer replenishment tanks

The mixing process is important for obtaining a good and consistent solution. It is important to follow the guidelines below whether the solution is mixed from liquid concentrates or powders. KODAK X-OMAT EX II and RP X-OMAT solutions are designed with rigid specifications and will give consistent results if mixed in the proper order and according to directions.

1. Water

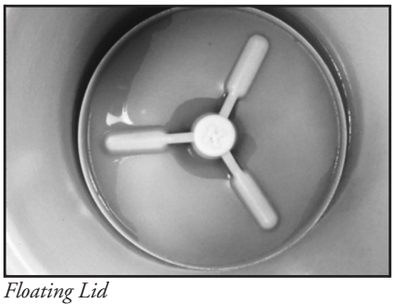
- Typically, the water should be added within 3% of the stated amount. This may be accomplished by accurately calibrating the mixing tanks. Differences greater than 3% could have an adverse effect on the properties of the solution and might be difficult to correct.
- The water temperature should be consistent with the manufacturer's instruction. If circumstances don't allow for this, a trial-and-error process can be used if the rate of dissolution of the concentrates is carefully observed. If the water temperature is colder than the recommendations, a longer stir time may be needed. However, agitation and temperature are critical factors in oxidation. In case of difficulty, the manufacturer should be consulted.

When mixing KODAK processing solutions, we recommend using water between temperatures of 70° to 80°F (21.1° to 26.7°C).

2. Mixing concentrate parts

- The agitation should be strong enough to provide adequate mixing but not excessive enough to cause oxidation.
- It is important to follow the recommended mix order. For instance, the Part A should always be added first. If the mix order is not followed, some components may not dissolve properly or unwanted chemical reactions may occur that could be harmful to the solution.
- Stirring time should be adequate and components should be completely dissolved before the next part is added. Please review the mixing instructions provided with each product for the recommended stirring times.
- The complete kit or concentrate part should be used to make a complete mix. Water should be used to rinse the bottles.

- Using a floating lid to prevent aerial oxidation is highly recommended. Developer and fixer replenisher solutions should be mixed only in quantities large enough to be used up within two weeks.



Floating Lid

Chemical Mixers

There are two basic types of commercial chemical mixers used in radiographic processing. Both types can be reliable in the preparation of solutions.

1. A specific gravity mixer will mix a solution by adding water until a determined specific gravity is reached. A probe is used that is calibrated to the specific gravity. An example of this type of mixer is the KODAK 100-J Chemical Mixer.
2. A volumetric mixer such as the KODAK Automixer II Plus employs an electronic probe to determine the necessary volume of the mix.

Important considerations with chemical mixers:

- Concentrates should always be added in the correct order. KODAK X-OMAT EX II and RP X-OMAT concentrates are designated to indicate mix order. The Part A should be added first, then Part B, then the Part C if applicable.
- Proper templates that match the bottles should be used.
- Thorough mixing is necessary after each addition.
- The mixed solution should not be uncovered or have too much contact with air as premature oxidation may occur.
- Ideally, the mixer should have a floating lid to protect the solutions from oxidation.
- If concentrates are used that have been repackaged by a distributor, the user should be certain the correct quantities of each concentrate are used.
- The concentrates should be examined to be certain there is no premature oxidation due to excessive handling.
- The manufacturer's recommended water-mixing temperature should be observed.

Important:

Mixing at colder than recommended temperatures may affect:

- Image quality
- Processor Control Stability
- Image Tone and Dye Stain

When mixing KODAK processing solutions, we recommend using water between temperatures of 70° to 80°F (21.1° to 26.7°C).

  - A new mix of developer and/or fixer should only be made when indicated by the solution level in the mixer.
- To aid in verifying that the chemistry is acceptable, the pH and specific gravity can be measured. It is important to make these measurements at the recommended temperatures for the instrument used.

pH and Specific Gravity of KODAK Processing Solutions for Mammography

Product	pH at 77°F (25°C)	Specific Gravity at 77°F (25°C)
KODAK X-OMAT EX II Developer and Replenisher (10 and 200 gallons)	10.40 to 10.50	1.070 to 1.080
KODAK RP X-OMAT Developer and Replenisher (10, 20, 200 gallons)	10.22 to 10.38	1.081 to 1.091
KODAK RP X-OMAT LO Fixer and Replenisher	4.25 to 4.45	1.080 to 1.100

While specific gravity—measured as the relative weight of a processing solution as compared with the density of water at 39.2°F (4°C)—can indicate over- or under-dilution, by itself it does not verify solution content. For example, a specific gravity test cannot determine whether critical components such as developer antifoggants are missing or have been depleted.

For demonstrating proper dilution, specific gravity tests can be done using hydrometers that can be purchased at a reasonable price. Measurements must be taken at the temperature at which the hydrometer was calibrated.

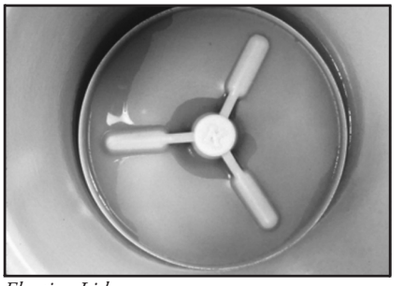
Caveats

- The variability of the mixer in terms of accuracy in delivering water or measuring specific gravity may cause variation in solution quality.
- Agitation and exposure to air could cause premature oxidation if it is excessive.
  - Check with the mixer manufacturer for the availability of oxidation kits.
  - For best results, follow the mixer manufacturer's suggested maintenance schedule.
- Do not process films while mixing chemistry.

Pre-mixed Solutions

The use of a solution mixed off-site and delivered to the end user's site is a common practice in the United States and Canada. The developer and fixer solutions are stored in a replenisher barrel or jug. There are some factors to consider in this circumstance to keep solutions stable:

- The solutions should be examined to determine if they are off-color.
- The date of preparation should be available to the user.
- A quantity of solution should be delivered that can be consumed within two weeks.
- The replenisher barrel should be an appropriate size for the volume of delivered chemistry to reduce contact with the air.
- A floating lid must be used in the replenisher barrel.



Floating Lid

Pre-mix Caveats:

- The age of the solution when it is delivered and the storage conditions prior to delivery can be factors in causing premature oxidation.
  - The age of the solution should be clearly labeled.
- Consistent mixing technique and equipment should be used to reduce variability of the solutions.
- For best results with mammography films, the solution should be used within two weeks of mixing.
- Use a floating lid.
- Clean the floating lid whenever new developer is added. Replenisher tanks should be cleaned every 2-3 months.

Storage

A well-designed concentrate is relatively stable if stored properly. At room temperature (70°F/ 21.1°C) concentrate solutions can have a shelf life of up to two years. A robust replenisher solution can stay relatively stable for several weeks if stored under proper conditions. The relative ratio of sulfite (preservative) to hydroquinone (developing agent) is a good indication of the shelf life of the concentrate and replenisher solution. KODAK X-OMAT EX II and RP X-OMAT solutions are specifically designed with optimum preservative levels for longer shelf-life.

Considerations for chemical storage:

- Store at temperatures between 70-80 (etc).
- Storage and use of chemicals at temperatures higher than recommended can accelerate oxidation.
- Use a floating lid to reduce oxidation.

Typically, developer and fixer replenisher solutions should be mixed only in quantities large enough to be used up within two weeks.

Oxidation

The developing agents in a developer solution readily react with oxygen. This process is called oxidation. Loss of developing agents from oxidation or from reaction with silver (exhaustion) will reduce the activity of the developer.

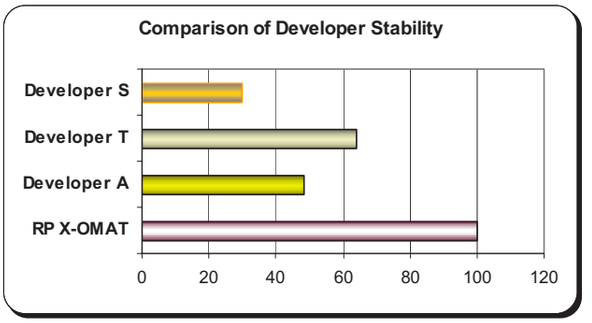
An antioxidant or preservative is a developer component which will slow the oxidation of the alkaline developer solution. This helps maintain the development rate. The ratio of preservative and developing agent is critical for effective protection from oxidation. In radiographic developer solutions, sulfite salts are commonly used as preservatives. In KODAK X-OMAT developer solutions (such as X-OMAT EX II and RP X-OMAT) the levels of preservative and buffer are carefully balanced with the developing agent to ensure long shelf life and consistent seasoning effects over the life of the solutions.

In a processing tank with elevated processing temperatures, developer oxidation can be accelerated. The rate of oxidation can be increased by the agitation caused by moving rollers. Evaporation may also occur under these conditions. This can result in precipitation of the developer components. Sometimes precipitation can lead to a build up on the tank walls or rollers and cause scratches on films or even impede the rotation of rollers. The developer in the processing tank will also carry over into the fixing tank. If these situations are observed it may be necessary to increase replenishment rates to compensate for these adverse effects by adding fresh developer. KODAK X-OMAT EX II and RP X-OMAT solutions are designed to be more efficient and robust and should not require excessive replenishment rates to give consistent processing results. The developer must be protected from oxidation. Increased replenishment can partially compensate for oxidation and exhaustion, however the use of a floating lid and proper chemical storage conditions are the best methods of preventing oxidation as well as avoiding the added cost and environmental impact of increased replenishment.

What is hydroquinone?

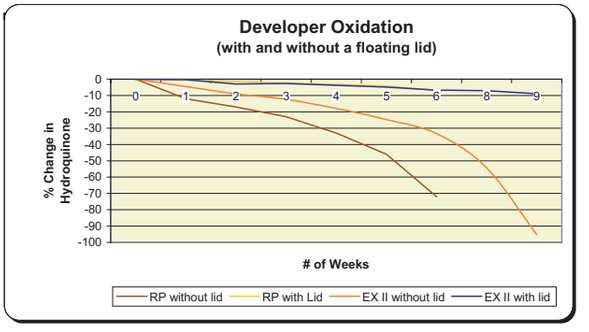
Why is it important?

Developing agents are responsible for the formation of metallic silver from the exposed silver grains of silver halide. For most black and white films, hydroquinone is used as the primary developing agent. It can rapidly develop films with high silver content in relatively short development times. Use of a more effective developing agent in the developer solution allows for lower patient exposure to achieve proper film density



"Relative stability" of KODAK and other manufacturers' developers determined by comparison of oxidation rates in a controlled aeration test.

Correctly mixed X-OMAT EX II and RP X-OMAT Developers are formulated to be very stable in the user's environment. However, even these chemistries, if improperly stored without a floating lid, will degrade over time as is illustrated in the following charts.



Effect of aerial oxidation on hydroquinone level KODAK X-OMAT EX II and KODAK RP X-OMAT Developers and Replenishers

Oxidation of the developer may also affect the image quality by decreasing speed, contrast, D-Max (area of highest optical density) and the shoulder (thus decreasing the contrast in the breast periphery) and making the tone of the film appear "warmer" or less blue as is illustrated in Figures 2 to 5.

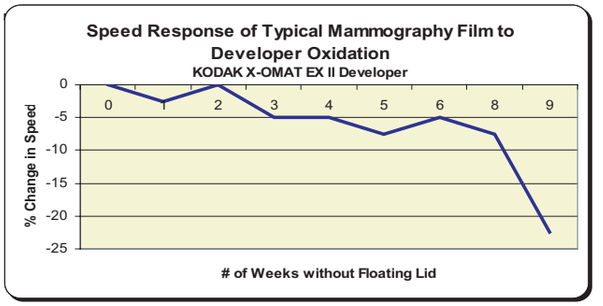


Figure 2

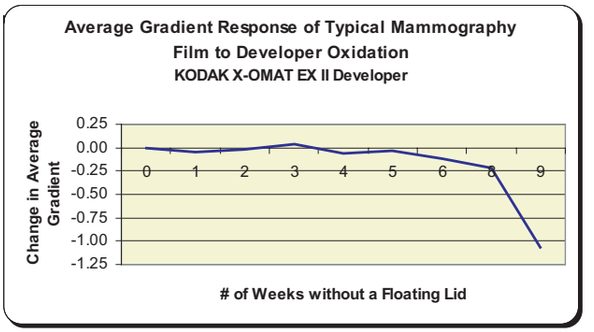


Figure 3

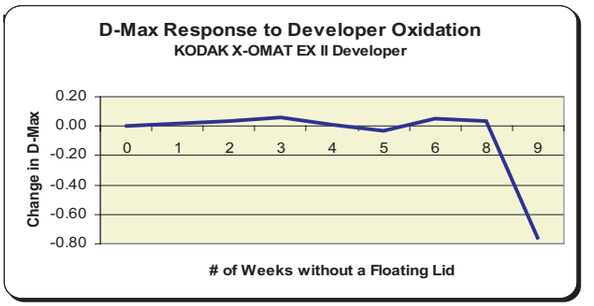


Figure 4

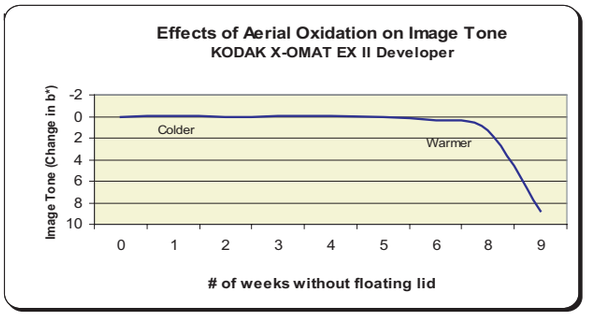


Figure 5

Mixed and stored properly, the developer replenisher solution may last up to 5 weeks but may otherwise degrade in less than two weeks.

Retaining the Developer

With present Kodak mammography films (such as KODAK MIN-R EV, MIN-R 2000 and MIN-R L films) and chemicals (KODAK X-OMAT EX II developer or KODAK RP X-OMAT developer and KODAK RP X-OMAT LO fixer), QC numbers change relatively little from fresh to seasoned developer so it is not necessary to retain developer for QC stability. In fact, depending on processing conditions over a period of months, retaining the developer may be detrimental to image quality. Image quality is at its best in a well-maintained processor with properly mixed chemistry. Kodak **recommends** changing the developer solution every 4 to 6 weeks during scheduled processor cleaning.

Type of Chemistry

The type of chemistry used can result in changes in contrast (average gradient), D-Max, the color (image tone and dye stain) and dose (speed) of clinical images. With KODAK MIN-R EV film, a change of 1.6 in average gradient and 0.50 in D-Max is possible depending upon the type of developer used. While some developers may increase average gradient, other sensitometric characteristics such as D-Max and speed will be adversely affected. Clinical images may not be acceptable to radiologists and diagnostic confidence could be compromised with such drastic sensitometric changes. Processing artifacts and/or noise may also be visible. For more information, please refer to the **KODAK Processing Chemicals Optimization Guide.**

Optimum results with KODAK MIN-R EV Film are obtained using KODAK X-OMAT EX II or KODAK RP X-OMAT Developer Replenisher and KODAK RP X-OMAT LO Fixer and Replenisher. Please refer to the MQSA Equivalency Statement in the Appendix.

Kodak does **not** recommend the use of KODAK Medical X-ray Developer Replenisher with KODAK MIN-R EV Film.

A Method for Evaluating Film Performance in Other Manufacturers' Developer Solutions

The United States Food and Drug Administration (FDA) Mammography Quality Standards Act (MQSA) Final Regulations, effective April 28, 1999, states that processing solutions be capable of developing films in a manner equivalent to the minimum requirements specified by the film manufacturer. Compliance guidance from the FDA recommends that facilities have documentation from the film or chemical manufacturer to support this.

To determine if another manufacturer's developer is within Kodak's acceptable range for KODAK Mammography Films, you will need to have access to a processor using fresh KODAK X-OMAT EX II Developer and Replenisher or RP X-OMAT Developer and Replenisher with the appropriate amount of KODAK RP X-OMAT Developer Starter for the type of film to be tested.

NOTE: *This procedure will take from 2 to 4 hours to perform. Do not attempt to perform this test unless both developers will be tested within that time frame on the same day. This test can best be performed using components of the complete KODAK System; i.e., processors and cassettes.*

Items Needed

1. A calibrated Sensitometer and a Densitometer that accurately reads above 4.5 O.D. (optical density).
2. Calibrated Digital Thermometer.
3. Stopwatch.
4. A box of KODAK MIN-R EV Film.
5. Freshly mixed KODAK X-OMAT EX II Developer and Replenisher or KODAK RP X-OMAT Developer and Replenisher and a bottle of KODAK RP X-OMAT Developer Starter.
6. Freshly mixed other manufacturer's developer replenisher and a bottle of that manufacturer's starter.

Setup, Exposure, and Processing the Film

Information to complete steps 1–4 can be found in the Service Bulletin No. 30 (revised January 2004), enclosed separately and also available on the Health Imaging website at http://www.kodak.com/go/health.

1. Fill the processor with KODAK X-OMAT EX II or KODAK RP X-OMAT Developer and Replenisher, adding Kodak's recommended amount of starter for the mammography film to be used.
2. Using the calibrated thermometer, verify that the developer temperature is set as per Kodak's recommendations.
3. Set the developer and fixer replenishment rates to Kodak's recommendations for processor type and film.
4. Measure the drop time for an 18 x 24 cm film and verify that the transport speed is set accurately.

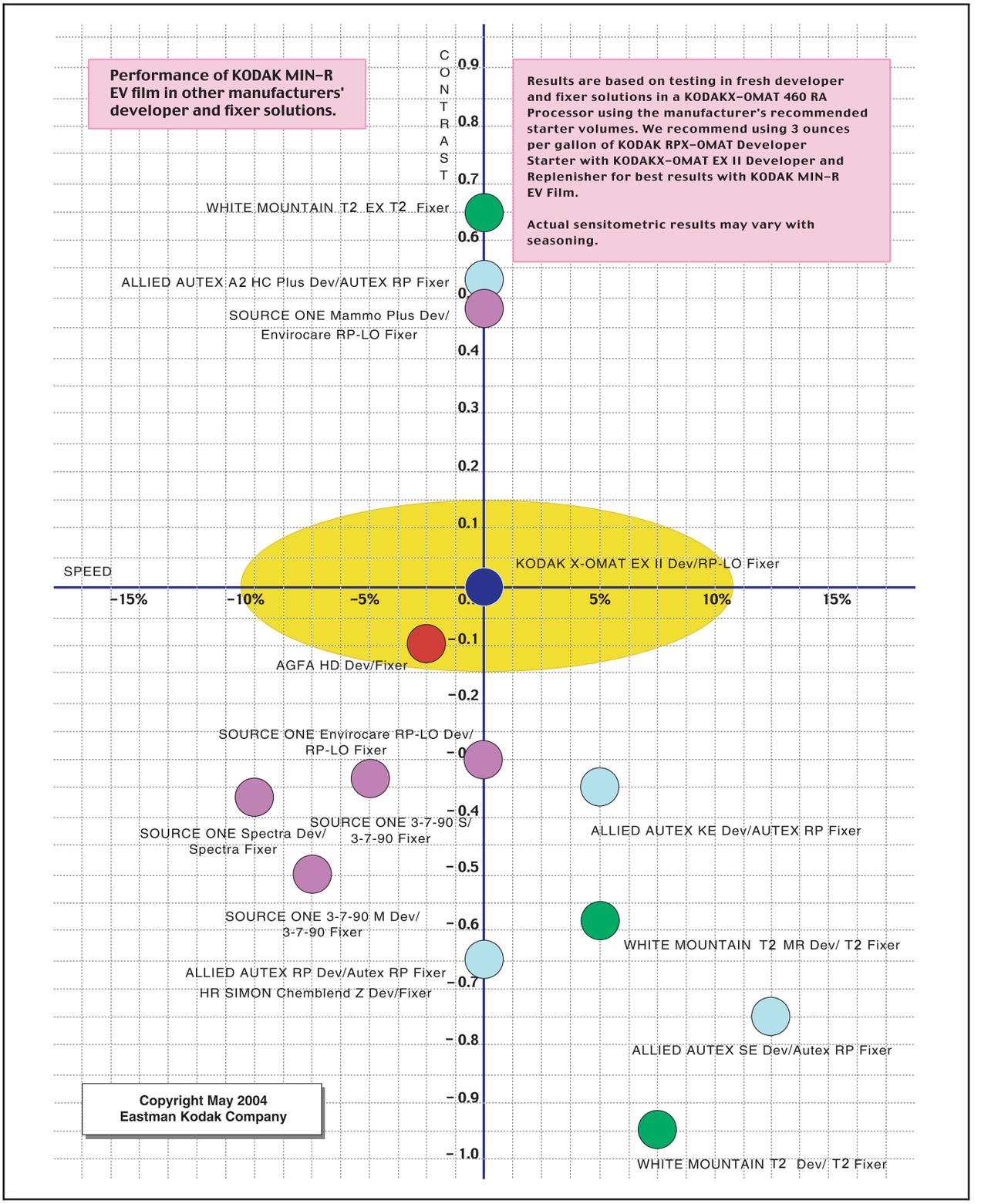
5. Set the sensitometer for green sensitivity. For KODAK MIN-R EV Film, be sure that the primary emulsion side faces the light-exposing source.
6. Expose three films.
7. Process the film on the right-hand side of the feed tray, emulsion side down.
8. Label all films. Indicate developer used, date, time, and any other relevant information.
9. Drain the developer solution, change the developer filter, and thoroughly rinse the tank, rack and developer-to-fixer crossover assembly. Repeat steps 1–8 using the other manufacturer's developer.

Use the developer manufacturer's recommended starter and replenishment volumes.

Evaluating the Films

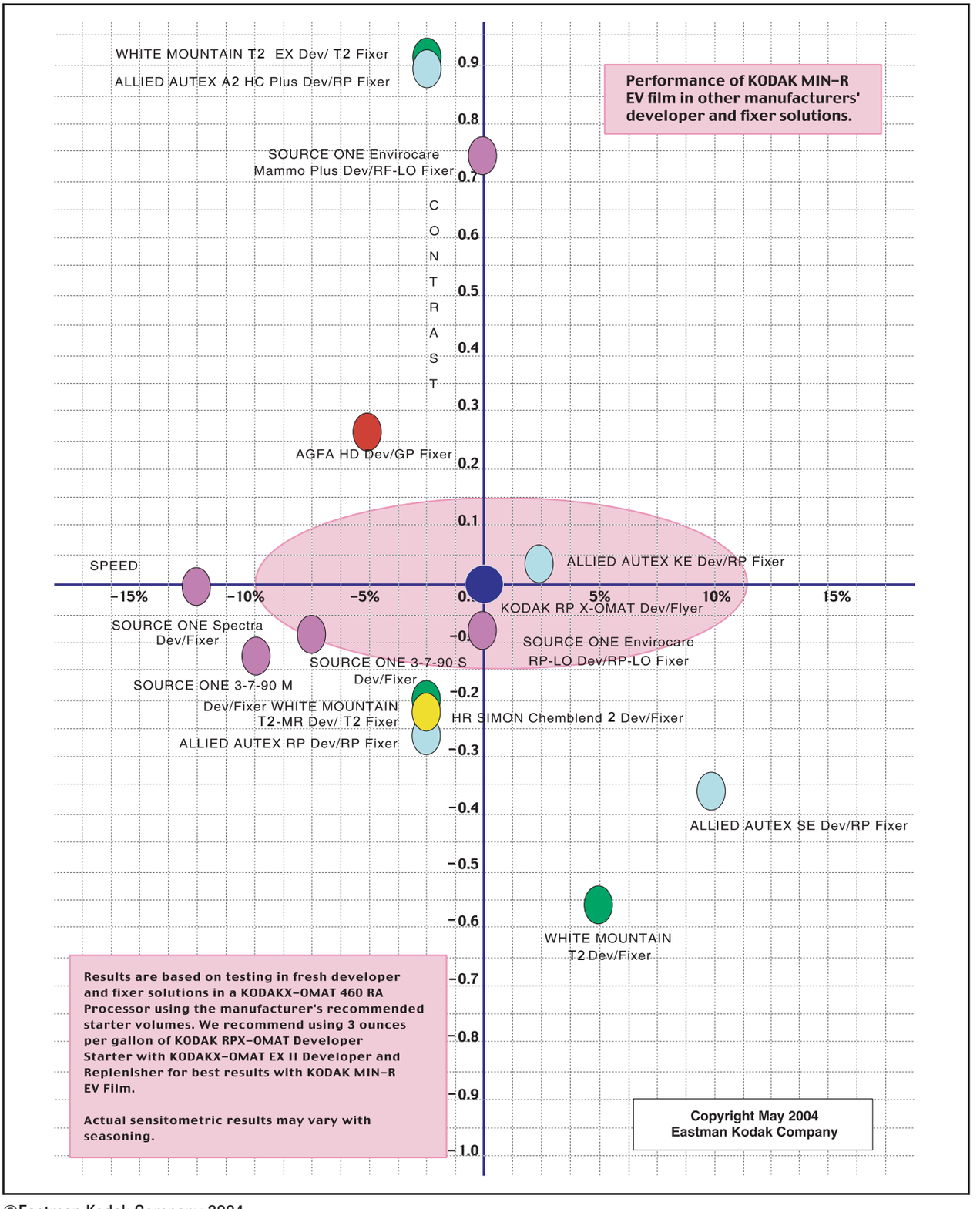
1. Read the films using the calibrated scanning densitometer or a spot reading densitometer. Note the speed value (step closest to 1.0 above gross fog) and the average gradient.
2. Average the speed and average gradient for the three films processed through KODAK Developer. Repeat for the films processed through the other manufacturer's developer.
3. Compare the speed and average gradient for the film processed in the other manufacturer's chemistry to that in KODAK X-OMAT EX II Developer and Replenisher or KODAK RP X-OMAT Developer and Replenisher.
4. Typically acceptable results are within the ellipse on the following page. This ellipse is defined by:
   - a maximum range of ±10% in optical density at the speed step
   - ±0.15 for average gradient of the films processed through KODAK Developer.

To verify adequate developing, the optical density of the 21st step should be measured. If the optical density is lower than 4.5 (for KODAK MIN-R EV Film with KODAK X-OMAT EX II or RP X-OMAT Developer), the test should be declared invalid. Other factors could affect the validity of the test. Please consult Kodak if you have questions.


Performance of KODAK MIN-R EV film in other manufacturers' developer and fixer solutions.
Results are based on testing in fresh developer and fixer solutions in a KODAKX-OMAT 460 RA Processor using the manufacturer's recommended starter volumes. We recommend using 3 ounces per gallon of KODAK RPX-OMAT Developer Starter with KODAKX-OMAT EX II Developer and Replenisher for best results with KODAK MIN-R EV Film.
Actual sensitometric results may vary with seasoning.
CONTRAST
SPEED
0.9
0.8
0.7
0.6
0.4
0.3
0.2
0.1
−0.1
−0.2
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1.0
−15%
−10%
−5%
5%
10%
15%
WHITE MOUNTAIN T2 EX T2 Fixer
ALLIED AUTEX A2 HC Plus Dev/AUTEX RP Fixer
SOURCE ONE Mammo Plus Dev/ Envirocare RP-LO Fixer
KODAK X-OMAT EX II Dev/RP-LO Fixer
AGFA HD Dev/Fixer
SOURCE ONE Envirocare RP-LO Dev/ RP-LO Fixer
SOURCE ONE Spectra Dev/ Spectra Fixer
SOURCE ONE 3-7-90 S/ 3-7-90 Fixer
ALLIED AUTEX KE Dev/AUTEX RP Fixer
SOURCE ONE 3-7-90 M Dev/ 3-7-90 Fixer
WHITE MOUNTAIN T2 MR Dev/ T2 Fixer
ALLIED AUTEX RP Dev/Autex RP Fixer
HR SIMON Chemblend Z Dev/Fixer
ALLIED AUTEX SE Dev/Autex RP Fixer
WHITE MOUNTAIN T2 Dev/ T2 Fixer
Copyright May 2004
Eastman Kodak Company

©Eastman Kodak Company 2004

Typical results versus KODAK X-OMAT EX II Developer


Performance of KODAK MIN-R EV film in other manufacturers' developer and fixer solutions.
WHITE MOUNTAIN T2 EX Dev/ T2 Fixer
ALLIED AUTEX A2 HC Plus Dev/RP Fixer
SOURCE ONE Envirocare Mammo Plus Dev/RF-LO Fixer
CONTRAST
AGFA HD Dev/GP Fixer
ALLIED AUTEX KE Dev/RP Fixer
SPEED
KODAK RP X-OMAT Dev/Flyer
SOURCE ONE Envirocare RP-LO Dev/RP-LO Fixer
SOURCE ONE Spectra Dev/Fixer
SOURCE ONE 3-7-90 S Dev/Fixer
SOURCE ONE 3-7-90 M Dev/Fixer WHITE MOUNTAIN T2-MR Dev/ T2 Fixer
HR SIMON Chemblend 2 Dev/Fixer
ALLIED AUTEX RP Dev/RP Fixer
ALLIED AUTEX SE Dev/RP Fixer
WHITE MOUNTAIN T2 Dev/Fixer
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-15%
-10%
-5%
5%
10%
15%
Results are based on testing in fresh developer and fixer solutions in a KODAKX-OMAT 460 RA Processor using the manufacturer's recommended starter volumes. We recommend using 3 ounces per gallon of KODAK RPX-OMAT Developer Starter with KODAKX-OMAT EX II Developer and Replenisher for best results with KODAK MIN-R EV Film.
Actual sensitometric results may vary with seasoning.
Copyright May 2004
Eastman Kodak Company

©Eastman Kodak Company 2004

Typical results versus KODAK RP X-OMAT Developer

Starter

What is Starter?

KODAK RP X-OMAT Developer Starter is a clear odorless solution used to "start" the seasoning process by adding bromide ions to the developer solution. While most starters contain some level of bromide, some include other ingredients such as acetic acid as well so it is important in most cases to match the appropriate developer and starter.

Bromide or other halide ions from exposed film, season into the developer during processing. Bromide is a restraining agent in developers. Starters serve to minimize chemical and sensitometric differences between fresh replenisher solutions and seasoned tank solutions by increasing the halide level prior to seasoning. Kodak tests starter recommendations with all film products, since different films will have varying seasoning effects in developer solutions.

Best results with MIN-R EV film are obtained using KODAK RP X-OMAT Developer Starter.

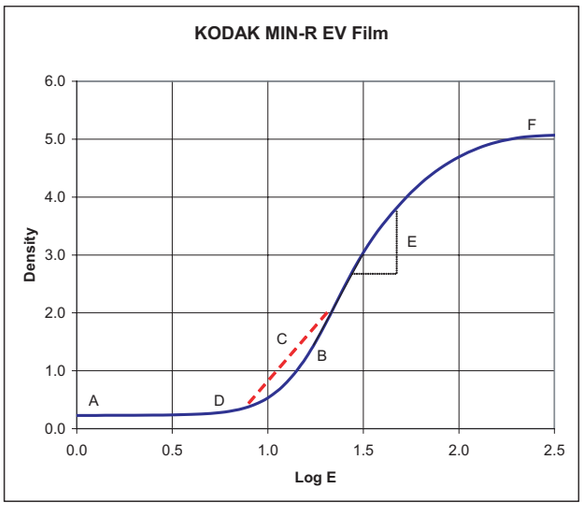
> For MIN-R EV film, the addition of 25 milliliters per liter or three ounces per U.S. gallon (3.8 liters) of KODAK RP X-OMAT Developer Starter is required to achieve appropriate image quality in dedicated and non-dedicated environments.

Why is Starter Important?

Starter is added to a developer when fresh solution has been placed in a processing tank. Starter will minimize changes in fog, speed and contrast during seasoning. The proper amount of starter should be used.

Over and Under Use of Starter

While the effects of over-and under-use of starter varies by film type as well as by different brands of starter, in general for some mammography films, not using starter will result in an increase in speed and D-max and a decrease in contrast on the H&D curve as well as the clinical image. Adding too much starter may also change speed, contrast and D-Max.



Legend

A = B+Fog

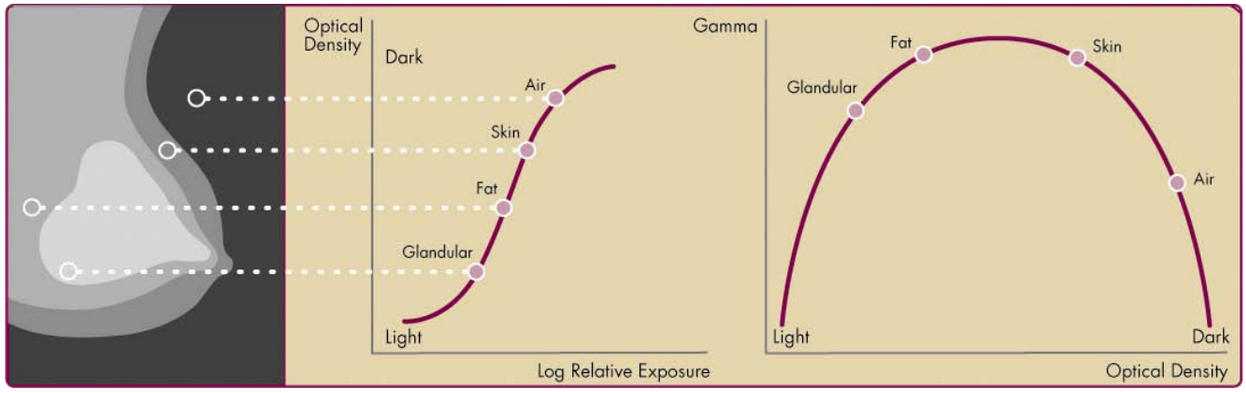
B = Mid-Density (Speed)

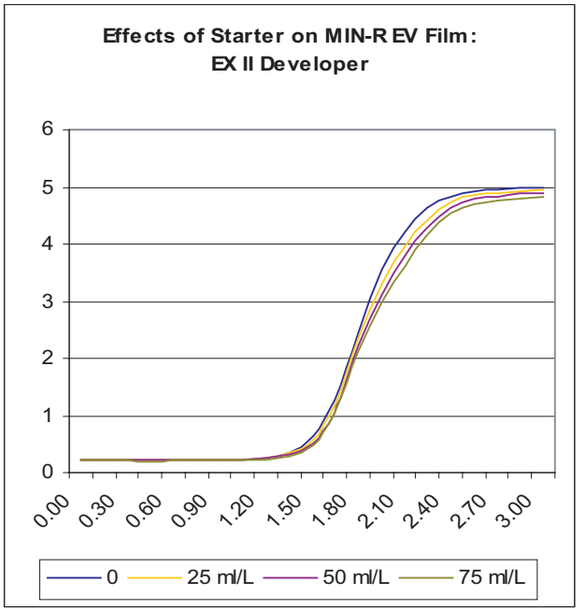
C = Mid-scale Contrast or Average Gradient

D = Toe (Whites)

E = Shoulder Contrast

F = D-Max





Effects of Starter on KODAK MIN-R EV Film in KODAK X-OMAT EX II Developer			
Parameter	No Starter	25 ml/L or 3 ounces/ gallon Starter	50 ml/L or 6 ounces/ gallon Starter
B+Fog	"="	=	"="
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↑↑↑	=	"↓"
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	↓↓↓	=	↑↑↑
Toe Contrast (Whites)	"="	=	↑
Shoulder Contrast ↑Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑	=	↓½
D-Max (Darkest)	½ ↑	=	-½↓

Baseline is 25 ml/L or 3 ounces/gallon Starter

Mid-Density (Speed) : ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

D-Max: ↑ is 0.10 change in optical density

Toe Contrast: ↑ is 0.05 change in Toe Contrast

Shoulder Contrast: ↑ is a 0.20 change in Shoulder Contrast

Effects of Starter on KODAK MIN-R EV Film in KODAK RP X-OMAT Developer			
Parameter	No Starter	25 ml/L or 3 ounces/ gallon Starter	50 ml/ L or 6 ounces/ gallon Starter
B+Fog	↑↑	=	"="
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↑	=	"="
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	↓	=	+↑½
Toe Contrast (Whites)	↓	=	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↓ ½	=	↓
D-Max (Darkest)	=	=	↓

Baseline is 25 ml/ L or 3 ounces/gallon Starter

B+fog: ↑ is a 0.01 change in B+fog.

Mid-Density (Speed): ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Shoulder Contrast: ↑ is a 0.20 change in Shoulder Contrast

D-Max: ↑ is 0.10 change in optical density

Summary: Speed decreases with the addition of starter. Contrast increases with additional starter.

Why is varying the amount of developer starter from Service Bulletin 30 not recommended to adjust process control speed and contrast?

Sometimes in an effort to stay within process control limits, varying amounts of starter are added. This defeats the purpose of doing daily process control. Eventually the bromide level in the processor will either revert to where it previously was or reach a new level of equilibrium and the QC values may again go out of control. It is better to find the root cause of the problem and take corrective action.

Replenishment

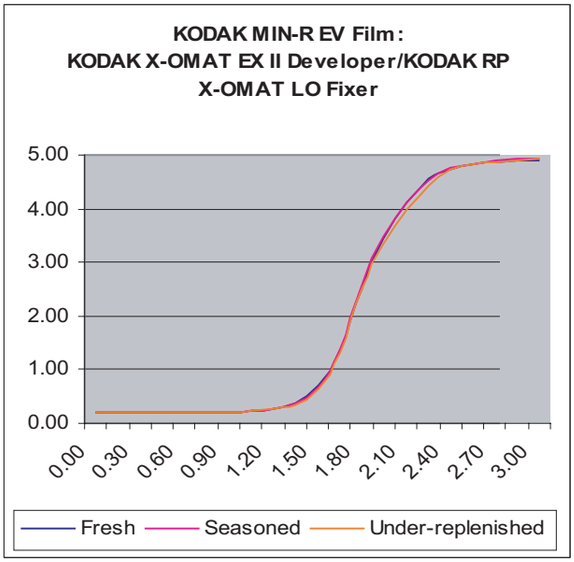
Replenishment is the addition of chemistry to the developer and fixer tanks to replace those depleted during the developing and fixing process. Proper replenishment rates will keep equilibrium and help maintain consistent processor QC.

Setting the proper replenishment rate is key to optimized image quality and stability.

- Rates should be established based on the average workload.
- If the workload changes (i.e., the number of films processed increases or decreases), the replenishment rate may need to be revised to reflect this change.
- Film should always be fed in the same way. If rates are set per 2 18 x 24 cm. films, then two films should always be processed together. If the rate is set per one 18 x 24 cm film, then only one should be processed at a time.
- The direction of the film, i.e., if fed lengthwise or sideways should always be the same.
- If the optical density of the phantom and clinical image is increased, bromide from the film builds up in the developer at an increased rate. To keep the process at equilibrium, the replenishment rates may need to be increased.

NOTE: *If replenishment rates are changed, it may be necessary to re-establish process control aims.*

Recommended starting points for developer and fixer replenishment rates and starter volumes for MIN-R EV film are published in Service Bulletin No. 30 (included separately). As illustrated in the charts below, over-replenishing with MIN-R EV film may result in decreased contrast. Under-replenishment will result in lower speed, lower shoulder (more visible skin line with a decrease in contrast in the periphery of the breast) and D-Max as well as a browner image.



MIN-R EV Film Response to Seasoning, Over and Under Replenishment KODAK X-OMAT EX II Developer and RP X-OMAT LO Fixer				
Parameter	**Over-replenished**	**Normal Starter**	**Normal Seasoning**	**Under-replenished**
Fog	=	=	=	=
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↑↑↑	=	·	"="
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	↓↓↓½	=	↑½	↑↑↑↑
Toe Contrast (Whites)	"="	=	"="	↑
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑½	=	↓	↓↓
D-Max (Darkest)	½↑	"="	"="	"="
Image Tone ↑ bluer ↓ browner/warmer	↑	=	↓	↓
Dye Stain ↓ (lower=bluer) Mainly visible on QC film	"="	=	"="	"="

Processed in a KODAK X-OMAT 460 RA Processor

"Normal" Starter [3 ounces/gallon (25 ml/L) KODAK RP X-OMAT Developer Starter] is the baseline.
"=" is equivalent to results obtained with "Normal" starter.

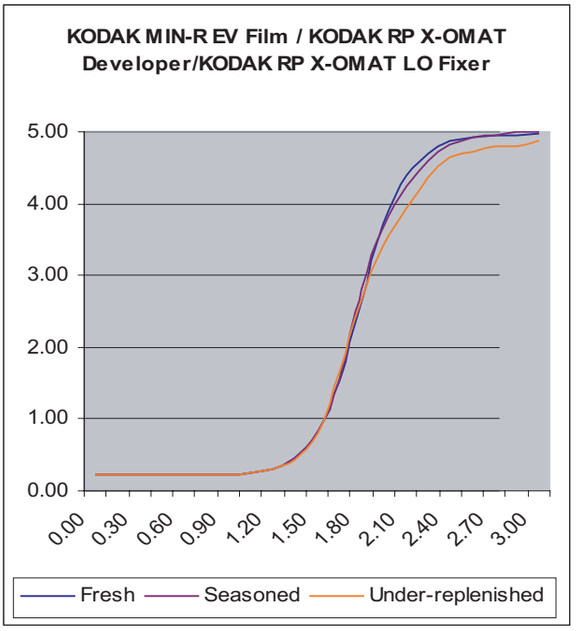
Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change in Toe Contrast

Shoulder Contrast: ↑ is a 0.2 change in Shoulder Contrast

D-Max: ↑ is 0.10 change in optical density


KODAK MIN-R EV Film / KODAK RP X-OMAT Developer/KODAK RP X-OMAT LO Fixer
5.00
4.00
3.00
2.00
1.00
0.00
0.00
0.30
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
Fresh
Seasoned
Under-replenished

MIN-R EV Film Response to Seasoning, Over and Under Replenishment KODAK RP X-OMAT Developer and RP X-OMAT LO Fixer				
Parameter	**Over-replenished**	**Normal Starter**	**Normal Seasoning**	**Under-replenished**
Fog	↑↑	=	=	=
Mid-Density measured at 1.0 above B+Fog (Speed Index)	↑	=	=	↓↓
Contrast (Average Gradient, Density Difference or Contrast Index) (Mid-scale)	↓	=	↑↑	"="
Toe Contrast (Whites)	↓	=	"="	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↓½	=	½↑	↑
D-Max (Darkest)	=	=	↓	↓
Image Tone ↑ bluer ↓ browner/warmer	"="	=	"="	"="
Dye Stain ↓ (lower=bluer) Mainly visible on QC film	"="	=	"="	"="

Processed in a KODAK X-OMAT 460 RA Processor

"Normal" Starter [3 ounces/gallon (25 ml/L) KODAK RP X-OMAT Developer Starter] is the baseline.

"=" is equivalent to results obtained with "Normal" starter

Mid-Density (Speed): ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change in toe contrast

Shoulder Contrast: ↑ is a 0.2 change in shoulder contrast

D-Max: ↑ is 0.10 change in optical density

Caveat

- Assumes the replenishment rates are set accurately and, if in a RA processor, that the rates are appropriately calibrated.

Summary: Over-replenishment will increase process control speed and decrease contrast while under-replenishing will decrease D-Max. Since the "seasoning" effects are small, it is not necessary to retain the developer when routine processor maintenance is performed on the processor.

Frequency of Changing the Developer Solution:

With present KODAK mammography films (such as KODAK MIN-R EV, MIN-R 2000 and MIN-R L films) and chemicals (KODAK X-OMAT EX II developer or KODAK RP X-OMAT developer and KODAK RP X-OMAT LO fixer), QC numbers change relatively little from fresh to seasoned developer so it is not necessary to retain developer for QC stability. In fact, depending on processing conditions over a period of months, retaining the developer may be detrimental to image quality. Image quality is at its best in a well-maintained processor with properly mixed chemistry. Kodak recommends changing the developer solution every 4 to 6 weeks during scheduled processor cleaning.

Fixer

During the fixing process, the development reactions are halted, the unexposed silver halide is fixed and "cleared." This removes the unexposed silver halide and leaves this area of the radiograph clear.

Fixer is often thought to be interchangeable but it plays a vital role in the photographic process. Of particular importance is its impact on the image tone, dye stain, archivability, and drying of clinical films.

Image Tone

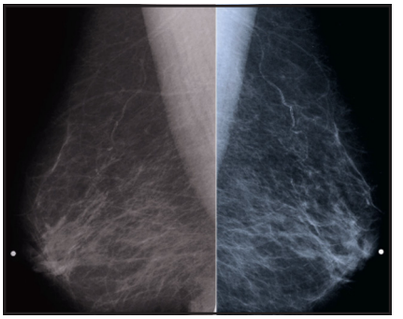
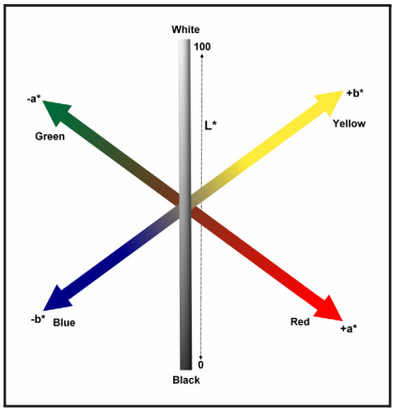


Image Tone of KODAK MIN-R 2000 Film with different chemistries. Images courtesy of the Diagnostic Imaging Center, Auburn, NY

Image tone is a measure of both the blue estar base and the silver image in a radiograph. The image will be very blue at low densities and less blue (brown) at high densities, creating an overall perception of image tone. For some films this can be affected by components in the developer and fixer. KODAK high tier developers and fixers are formulated to give a "colder" (more blue) image tone with KODAK films.

All else being equal (developer, fixer, film, processing conditions), image tone is also affected by an increase in optical density as is illustrated in the figure below.

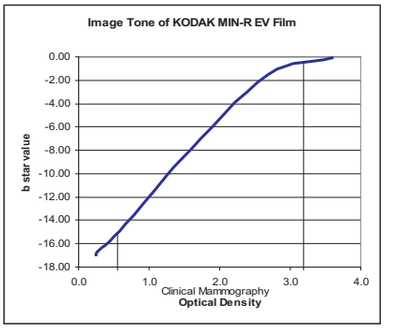


What is b*?

The b* parameter is taken from the widely used international CIELAB standard color model which is based on the human sensitivity to the visual spectrum of light.

b* is based on the colorimetric measure of how blue or yellow an image is. The more negative the value, the bluer the image. The more positive the number, the yellower the image.

For more information, please consult: Berns, Roy S.. *Billmeyer and Saltzman's principles of color technology*, 3rd ed. English (New York, USA: John Wiley & Sons.) 2000.



- The more negative the b* value, the bluer the image tone.
- The more positive the b* value, the yellower/browner the image tone.
- As the optical density increases, the image tone becomes more yellow/brown (warmer).
- All films react similarly.

Dye Stain

Following the film manufacturer's recommendations for fixer in terms of type, replenishment rates, etc., is just as important as for developer since mammography films may be more difficult to clear and image storage requirements are longer than conventional films.

Additionally, systematic replenishment rate reduction to minimize costs and environmental impact, and fixer reuse has become more prevalent. In some extreme processing situations, KODAK MIN-R EV Film may exhibit dye stain. Dye stain may be recognized by a general pinkish or lavender tint in a D-min area of the film.

Dye stain may be more pronounced in the following situations:

- A combination of electrolytic silver recovery with reduced fixer replenishment rates.
- The use of fixers exhibiting a high pH and/or high hardener level. *(**NOTE:** It is normal for the pH of fixer to increases with seasoning; increasing the fixer replenishment rate may help control the pH.)*

It may be possible to reduce dye stain by:

- Checking that the fixer has been properly mixed.
- Increasing the fixer replenishment rate.
- Verifying that the film is being processed in the appropriate cycle.
- Checking the temperature of the fixer solution in the processor, and increasing to approximately 5°F (3°C) above the developer temperature, if possible.
- Checking the temperature of the wash water in the processor, and increasing, if possible. (Refer to Service Bulletin No. 30, revised January 2004 for general processor information.)
- If using electrolytic silver recovery, increasing the fixer replenishment rate by 10 to 20 ml/film increments.
- Consider use of a different method of silver recovery.

A Method for Evaluating Film Performance in Other Manufacturers' Developer and Fixer Solutions for Image Tone and Dye Stain

To determine if another manufacturer's developer and fixer solutions are within Kodak's acceptable range for KODAK Mammography Films, you will need to have access to a processor using fresh KODAK X-OMAT EX II Developer or KODAK RP X-OMAT Developer and Replenisher with the appropriate amount of KODAK RP X-OMAT Developer Starter for the type of film to be tested and KODAK RP X-OMAT LO Fixer and Replenisher.

***NOTE:** This procedure will take from 2 to 4 hours to perform. Do not attempt to perform this test unless both developers and fixers will be tested within that time frame on the same day. This test can best be performed using components of the complete KODAK System; i.e., processors and cassettes. It may be performed at the same time as the film performance test in other manufacturers' developer solutions.*

Equipment Needed

1. A calibrated Densitometer.
2. Calibrated Digital Thermometer.
3. Stopwatch.
4. A box of KODAK MIN-R EV Film.
5. Freshly mixed KODAK X-OMAT EX II Developer or RP X-OMAT Developer and Replenisher and a bottle of KODAK RP X-OMAT Developer Starter and KODAK RP X-OMAT LO Fixer and Replenisher.
6. Freshly mixed other manufacturer's developer replenisher and a bottle of that manufacturer's starter and the manufacturer's fixer replenisher.
7. RMI-156 Phantom.

Setup, Exposure, and Processing the Film

Information to complete steps 1-4 may be found in the included Service Bulletin No. 30 (revised January 2004), and may also be found on the Kodak website.

1. Fill the processor with KODAK X-OMAT EX II or KODAK RP X-OMAT Developer and Replenisher, adding Kodak's recommended amount of starter for the mammography film to be used and KODAK RP X-OMAT LO Fixer.
2. Using the calibrated thermometer, verify that the developer temperature is set as per Kodak recommendations.
3. Set the developer and fixer replenishment rates to Kodak's recommendations for processor type and film.
4. Measure the drop time for an 18 x 24 cm film and verify that the transport speed is set accurately.
5. Establish exposure technique.
   - Use the quality control phantom (e.g. the RMI -156 phantom) or 4-5cm of breast equivalent material.
   - Use the same mode and/or kVp for the subsequent images.
   - Expose and process one MIN-R EV Film using the same mode and/or kVp as you normally would.
   - Measure the background densities at the same point in each image.

6. Label all films. Indicate developer and fixer used, date, time, and any other relevant information. Drain the developer and fixer solutions, change the developer filter, and thoroughly rinse the tanks, racks and developer-to-fixer crossover assembly.

   Repeat steps 1–6 using the other manufacturer's developer and fixer.

   Use the developer manufacturer's recommended starter and replenishment volumes.

   Ensure that the background density for the phantom is within +/- 0.03 of the "control" film.

Evaluating the Films

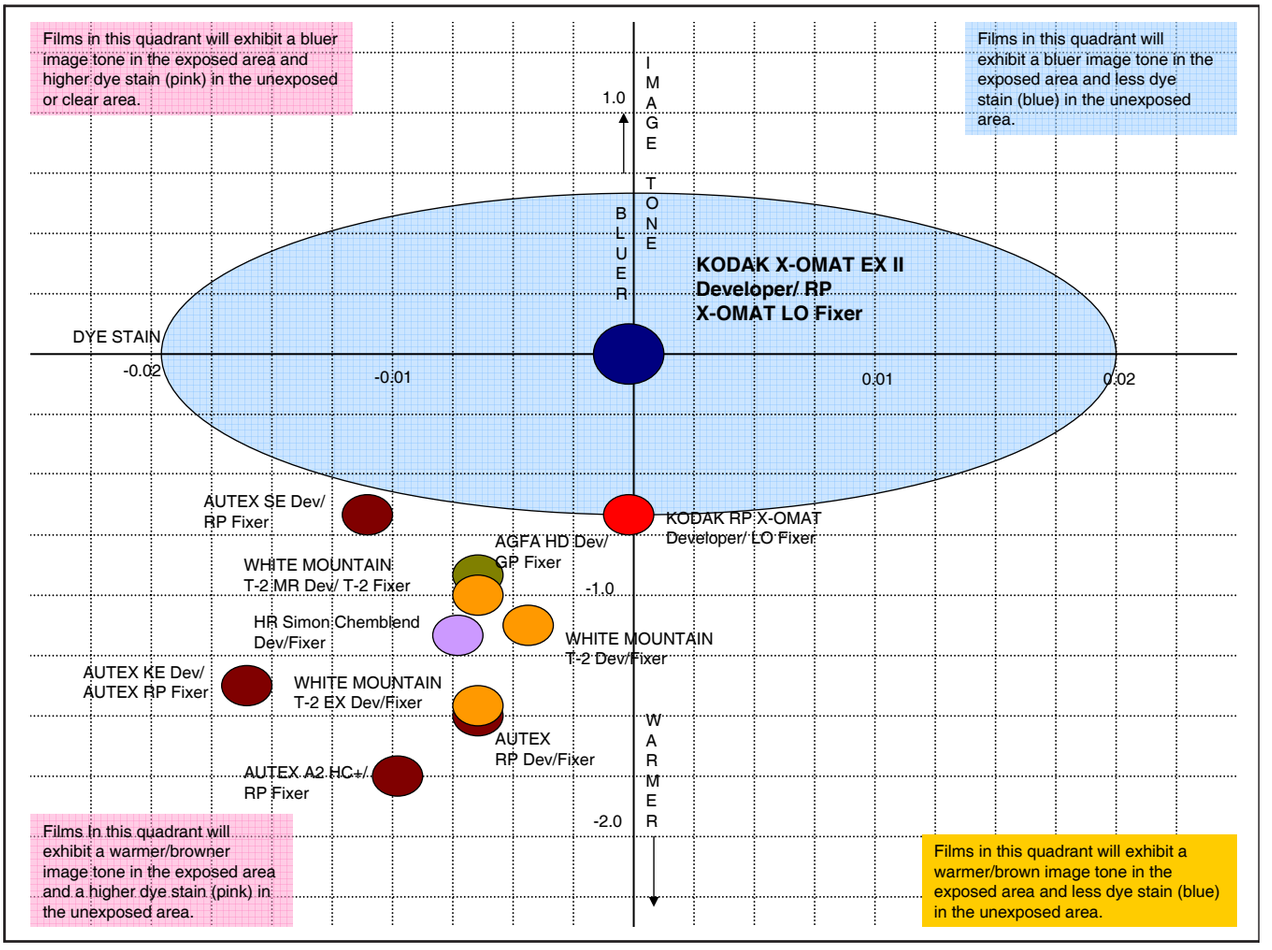
View the films under your typical conditions for lighting, masking and view box illumination. The films should be compared on the same viewbox.

Compare the color of the image processed through the KODAK developer and fixer to that of the image processed through the other manufacturer's developer and fixer.

Typically acceptable results are within the ellipse shown below. This ellipse is defined by:

- A maximum range of +/-0.7 in b* units for image tone
- A maximum range of +/- 0.02 for dye stain

Developers and fixers within the ellipse meet Kodak's minimum requirements for dye stain and image tone with KODAK MIN-R EV Film. The ellipse is defined by +/-0.7 b star units for Image Tone and 0.02 units in Dye Stain. These levels of change in image tone and dye stain have been observed to be "noticeable differences" by typical viewers.


Films in this quadrant will exhibit a bluer image tone in the exposed area and higher dye stain (pink) in the unexposed or clear area.
Films in this quadrant will exhibit a bluer image tone in the exposed area and less dye stain (blue) in the unexposed area.
IMAGE TONE
1.0
BLUER
KODAK X-OMAT EX II Developer/ RP X-OMAT LO Fixer
DYE STAIN
-0.02
-0.01
0.01
0.02
AUTEX SE Dev/ RP Fixer
KODAK RP X-OMAT Developer/ LO Fixer
AGFA HD Dev/ GP Fixer
WHITE MOUNTAIN T-2 MR Dev/ T-2 Fixer
-1.0
HR Simon Chemblend Dev/Fixer
WHITE MOUNTAIN T-2 Dev/Fixer
AUTEX KE Dev/ AUTEX RP Fixer
WHITE MOUNTAIN T-2 EX Dev/Fixer
AUTEX RP Dev/Fixer
WARMER
AUTEX A2 HC+/ RP Fixer
-2.0
Films in this quadrant will exhibit a warmer/browner image tone in the exposed area and a higher dye stain (pink) in the unexposed area.
Films in this quadrant will exhibit a warmer/brown image tone in the exposed area and less dye stain (blue) in the unexposed area.

©Eastman Kodak Company 2004

Hypo Retention

Hypo retention is a significant concern with many films, particularly films that need to be stored for long term viewing of over 20 years such as mammography films.

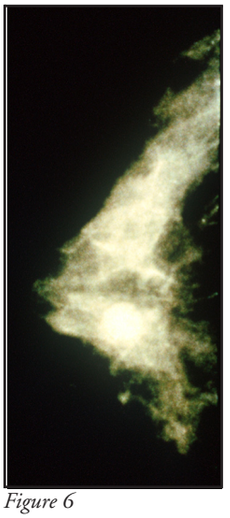
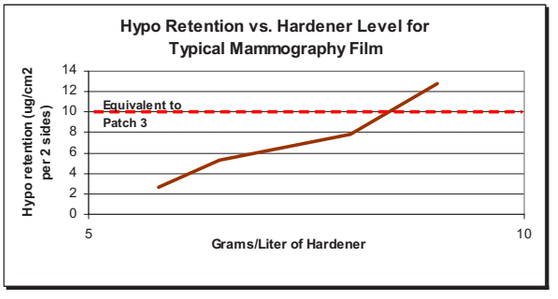


Figure 6

Thiosulfate from the fixer is retained in the emulsion if it isn't adequately removed by washing. The residual thiosulfate will decompose over time and the sulfur will add density or destroy the silver image often leading to a yellowing of the image as illustrated in Figure 6. Poor washing can result from the use of a fixer with a very low pH. This would restrict the film swell and cause inadequate washing.

Many fixers have a high level of hardener to allow film to transport in processors with small, weak dryers. This can also lead to poor washing.



Unfortunately, the effects on residual hypo may not be noticed for many years. RP X-OMAT LO Fixer was formulated considering the effect on hypo retention, dye stain and drying when processing KODAK films.

Assessing the Results of the Fixer (Hypo) Retention Test

A fixer (hypo) retention test should be performed regularly, i.e., at least quarterly, to make sure mammography films are properly washed and retain a minimal amount of fixer. Excessive fixer retention by the film may result in image degradation over time. It would then be of less or no value when making comparisons with subsequent mammographic studies. The procedure is outlined in the instructions included in the Hypo Retention test kit.

It is important to note the following points regarding assessing the results of the test:

- The Hypo Test Solution must be applied to the primary emulsion side of KODAK MIN-R EV Film. (There should be little or no hypo retention in secondary-emulsion side.)
- The KODAK Hypo Estimator (Cat No. 196 5847), the test tool used to estimate the amount of retained fixer, or hypo, on processed radiographs, contains four colored sections (1–4) which indicate the estimated grams of thiosulfate ion per square meter of film, 0.01, 0.02, 0.05, and 0.12, respectively.
- The KODAK Hypo Estimator is a generic test tool for use with all types of photographic papers, films, and processed radiographs.

> The color of the test spot on KODAK MIN-R EV Film may differ in color from the patches printed on the estimator, making it difficult to judge which color patch most closely matches the test spot.
>
> – A yellowish, greenish, or brownish tone may result.

- To minimize the difficulty in making a visible or subjective comparison, use a spot-reading densitometer to make optical-density measurements.
  - Make the first measurement after laying the clear central portion of the estimator in its plastic sleeve over the damp spot on the film.
  - Make at least two additional measurements through the color patches on the estimator, the plastic sleeve in which the estimator is enclosed, and a clear portion of the film.
  - The optical-density reading which comes closest to the reading taken from the test spot indicates the best match.
- The test spot should not be darker than the third patch on the estimator, indicating approximately 0.05 grams of retained fixer per square meter of film.

Caveats:

- Perform the fixer retention test in normal lighting conditions (avoid bright light or sunlight).
- Perform only on a freshly processed film, or one that has been processed no more than two weeks previously.
- The shelf life of the test chemicals is approximately two years, assuming the chemicals have been properly stored with the cap tightly closed, within the required environmental temperature range, etc.
- Process another film and repeat the tests if failing results are obtained.
- If failing results are obtained after repeating the test, consider replacing the test solution first if the solution is older than two years (or its age is unknown), if the conditions under which it has been stored are unknown, or if it is possible that the cap on the bottle may not always have been tightly closed.
  - When purchasing a new bottle of test solution, write the date it is first opened on the bottle.
- If failing results are obtained after repeating the test, and the test chemicals are not in question, check the quality of your fixer and verify that the incoming water temperature is set appropriately. Then, contact the processor service company or your local Kodak representative.

C. Washing and Water

Residual thiosulfate (hypo) and dye are removed during the wash cycle. Film artifacts may result if the wash is not thorough. Colder wash temperatures will increase hypo retention and dye stain and may also affect image tone.

For best results the water temperature in the processor wash tank should be between 50–75°F (10–23.9°C).

The quality of the water itself may be a factor in the variability of a developer or fixer. The water used should be as pure as possible. Although processing solutions often contain sequestering agents for metals, if the water has a high metal content they may not be totally effective. Water may also contain other impurities or biological growth that may cause processing problems. Heavy metals in the water can lead to developer oxidation. It is important to use the appropriate filter for incoming water.

A 50-micron filter is recommended for KODAK processors. Water filters should be changed on a regular basis according to local water conditions. (Note: This may not be the responsibility of the processor maintenance facility.)

D. Drying

Drying prepares the film for handling, viewing, and storage by removing excess water and is the last stage of hardening. The physical characteristics of KODAK MIN-R EV Film should allow for good drying.

***NOTE:** Over-dried films may exhibit drying artifacts that are visible on transmitted light (visible through the film). MIN-R EV film may not need the higher dryer temperatures of MIN-R 2000 film.*

Factors that Affect Drying

- Processor design
- Venting
- Temperature
- Humidity
- Quality of chemistry
- Film volume (i.e., serial unload, batch processing)

A blower in the processor supplies heated air to the dryer section. Most of the warm air is recirculated; the rest is vented to prevent buildup of excessive humidity in the dryer.

Proper processor ventilation is important to achieve proper film drying and decrease surface-pattern, or drying, artifacts. Refer to: Service Bulletin No. 101 (October 1992), Dryer Venting Requirements for All KODAK X-OMAT Processors, publication No. N-923. (Technical Information Bulletin 3111 may be found in the Appendix.)

Venting:

Excessive ventilation results in high evaporation rates and oxidation of the developer. This often seems to correlate with soft shoulder (skin line and breast periphery visibility) and non-uniform development issues.

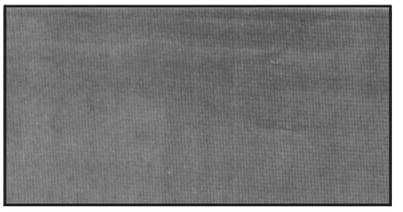
Under-ventilation tends to result in condensation related problems and often low level fixer contamination in the developer. The condensation may cause the developer to become dilute, thus possibly affecting image quality and daily QC charts.

Pressure imbalance in a through-the-wall installation is also a concern and may result in similar problems. High pressure on the feed side of the processor acts like over-ventilation, lower pressure on feed side of wall acts like under-ventilation.

The dryer temperature should always be set as low as possible while still being consistent with good drying. Use of a lower setting will also result in energy savings for processor operation.

The dryer temperature should never exceed the film manufacturer's recommendations. A common tendency is to raise dryer temperature higher than recommended, especially in response to films not thoroughly dried, or still tacky, exiting the processor. Over-dried films usually exhibit severe drying artifacts that are visible on transmitted light (visible through the film) as well as on reflected light (visible on the surface of the film).

The quality of the chemicals, both developer and fixer, and replenishment rates and processor ventilation should be evaluated and properly adjusted.



Shoreline pattern

Factors affecting drying and film transport/artifacts

Note that drying or surface patterns that are visible only on reflected light are not usually artifacts; they can usually be considered normal and acceptable. When the film surface is closely examined in reflected light (the primary emulsion side of KODAK MIN-R EV Film), slight drying patterns close to the film edges may be visible when the film has been properly dried using the lowest setting as recommended.

Troubleshooting Dryer Concerns

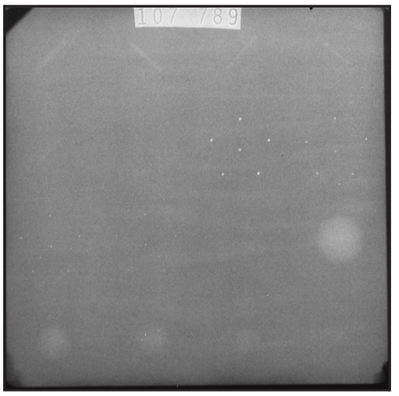
Problem Cause:	Solution:
Depleted, oxidized, or poor-quality processing chemicals.	Replace processing chemicals with fresh solutions. – Check replenishment rates and adjust according to the film manufacturer's recommendations. – Use processing chemicals recommended by the film manufacturer.
Poor squeegee action at the wash rack exit or entrance to squeegee.	Adjust or replace the wash rack exit squeegee.
Clogged, missing, or out-of-position dryer air tubes; non-uniform or excessive airflow in dryer.	Replace/clean air tube(s).
Inadequate processor venting.	Check processor ventilation.
Excessively high dryer temperature.	Reduce dryer temperature to minimum required to produce dry films.
Very cold wash water.	Provide wash water within the recommended temperature range.

"Solutions" should be performed by qualified personnel trained to perform the necessary task.

Uneven Density Patterns

Description:

- Pattern of plus or minus density
- May appear either as a band or a diffuse region
- Readily seen on a flat field or phantom, rarely in the clinical image
- Can appear across the image, but seen most often in a uniform phantom along the chest wall side of the image



Probable Cause or Causes:

The density pattern may be caused by a combination of factors in the exposing and processing of the film.

- Grid/cassette holder
  - Grid motor
  - Grid artifact/defect
  - Carbon fiber top damage
- Dryer
  - Dryer temperature too high
  - Air tubes blocked or obstructed
  - Buildup on dryer rollers
  - Squeegee rollers
  - Dryer venting
- Processor
  - Hesitation in developer rack
  - Stubbing in developer rack
  - Processor type
    - Some processors have a better path through the developer, wash and dryer (e.g. MIN-R Mammography or X-OMAT 5000 RA processor)
    - Note: In deep tank processors, test films should be processed emulsion up and down to determine best orientation for uniformity.
    - Films must be processed emulsion down in X-OMAT M35M, M35A-M and MIN-R Mammography processors.
- Chemistry
  - Type and/or quality of the chemistry
    - Mixed and replenished properly

NOTE: *High contrast developers may increase the visualization of breast structure. Consequently, they may also enhance the visualization of any anomalies present in the imaging chain. The visualization of grid and dryer patterns may be more pronounced with these developers.*

Please refer to the *"Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film"* in the appendix for a procedure to isolate non-uniformity artifacts.

Not all artifacts can be totally eliminated. It may be helpful to use the concept of ALARA (as low as reasonably achievable) when attacking artifacts. If they can be easily eliminated, they should. If the artifact is difficult or expensive to eliminate and is subtle (not mimicking or obscuring clinical information), it may be tolerable. The medical physicist should consult with the interpreting physician as to whether the artifact is tolerable.

Screens

Cleaning Mammographic Intensifying Screens

Maintaining clean mammography intensifying screens and cassette interiors will reduce the occurrence of minus-density artifacts caused by dust or dirt. Intensifying screens and cassettes should always be cleaned following the recommendations of the manufacturer. Only Kodak screen cleaning solutions, i.e., KODAK MIN-R Screen Cleaner Wipes or KODAK MIN-R Screen Cleaner) should be should be used on KODAK Mammography screens and cassettes.

New screens and cassettes must be cleaned prior to first use and prior to screen/film contact test.

Mammography screens should be cleaned at least once a week, or more frequently as necessitated by environmental conditions to reduce shadow images caused by dust and dirt. (If it is necessary to clean the screens more often than once a day, attention to the darkroom environment itself may be necessary; refer to Troubleshooting the Darkroom section, page 9.)

Recommended Screen Cleaning Procedure

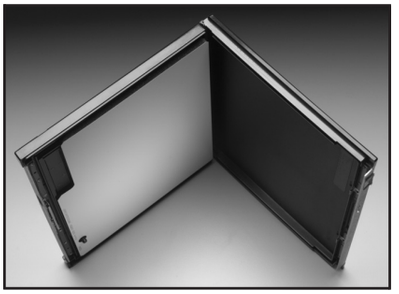
1. Choose a clean location to clean screens and cassettes.
   - If working on a countertop in the darkroom used for processing mammography film, wipe the outside of the cassettes and clean the countertop with a damp cloth prior to cleaning the screens.
   - Manage cassettes so they are empty at the time of cleaning (end of the day is usually best).
   - Avoid replacing film previously loaded into cassettes back into the film box or film bin, since this could introduce dust into the film supply.
2. Clean the inside plastic cover of the cassette (tube side panel) using a KODAK MIN-R Screen Cleaner Wipe or a lint-free wipe that has been dampened with a small amount of the KODAK MIN-R Screen Cleaner. If dust is noted at screen chest wall edge, very carefully clean under the foam using a cotton swab or compressed air.
3. Dry the cover. It may be advisable to use a camel's-hair brush or other soft lint-free brush to remove any dust accumulated in the corners of the cassette cover and along the hinge. Such dust may not be easily reached with the dampened cloth.
4. Gently rub across the screen with a KODAK MIN-R Screen Cleaner Wipe (or a lint-free wipe moistened with a small amount of KODAK MIN-R Screen Cleaner).

Stained screen due to improper cleaning.

- Avoid the use of abrasive wipes such as surgical gauze pads.
- Avoid excessive pressure or rubbing on the screen.
- Avoid pouring the screen cleaner directly onto the screens or cassettes.
- Use the minimum amount of screen cleaner needed to moisten the wipe.
- Excess screen cleaner will not improve screen cleanliness, will prolong the drying period, and may stain the screen.
- Clean around any labels on the screen (e.g., those used to individually number the cassettes).
- DO NOT WIPE THE SCREEN DRY. Allow the screen surface to air dry so that the full effects of the screen cleaner may be realized.
- A solution of 70% isopropyl alcohol may be used occasionally to remove stubborn dirt or dust.
- After using 70% isopropyl alcohol, a KODAK MIN-R Screen Cleaner Wipe (or a lint-free wipe pre-moistened with a small amount of KODAK MIN-R Screen Cleaner) must be used following the procedure outlined above.

The use of 70% isopropyl alcohol should be limited to occasional use only.

5. Stand the cassettes on edge to dry.
- Allow the screens and cassettes to completely air dry before returning them to service.
- Loading film into a cassette with wet screens may damage the film and lead to staining of the screens.



6. Inspect the screen and cassette cover for any stray particles of dust.
- An ultraviolet, or black, light is helpful in determining if screens and cassettes are clean.

> Limit exposure to the ultraviolet light and observe appropriate safety precautions for eyes, face, and exposed skin: do not look directly at the light.

7. Reload the cassette with film.

   Wait at least 5 minutes after loading before using.
8. Reclean the countertop, if the cleaning procedure was done in the darkroom.
9. Between regular cleanings, a camel's-hair brush may be used to remove dust particles from the cassette and screen surface. Care should be taken when using any brush to protect the screen surface from scratches, which will degrade image quality.
10. Each intensifying screen and cassette should be marked with a unique number to facilitate locating a specific cassette suspected of requiring cleaning or inspection.

Kodak recommends the use of a soft lint-free untreated cloth. The use of other manufacturers' dusting clothes and screen cleaning devices or cleaner with KODAK MIN-R EV 150, MIN-R EV 190, MIN-R, MIN-R 2000 or MIN-R 2190 screens is not recommended as their formulas, raw materials and photoactive properties may change without notice.

Procedure for Uniformity of Screen Speed

Objective

To assess the uniformity of the radiographic speed of image receptors routinely used for mammographic imaging.

Frequency

- Prior to putting new cassettes into use
- Yearly or as locally mandated

Caveats for Success

- Set aside enough film from a single emulsion lot to perform the test on all cassettes.
- Automatic Exposure Control (AEC) of the mammography x-ray unit must be performing within standards.
- Processor must be in control.
- Feed all films through the same side of the processor.
- Measure the optical density of the film in the same place on each film.

Required Test Equipment

- The image receptors normally used for mammographic imaging.
- Film of the type used for mammography. Note that the use of a single emulsion lot of film, and most preferably, film from a single box, is very important in obtaining useful results from this test.
- A 2.0-cm-thick cassette-sized phantom made of either acrylic or BR-12. Some provision should be made on the phantom to allow density measurements to be made in the same place on each of the test radiographs.

  If density measurements are not taken from the same location, significant variation can be obtained due to variation in beam intensity.
- A spot-reading densitometer.

Test Procedure Steps

1. Identify all of the image receptors (cassettes) of each size and type to be evaluated with some form of numbering system for further reference.
2. Select one of the cassettes and load it with a sheet of film from the box set aside for this test. Record on the data form the specifics of the image receptor being evaluated and the emulsion number of the film used for the test.

   This cassette will be called the control cassette.
3. Select the mammographic imaging mode and kVp most commonly used for clinical examinations (e.g., contact, grid, 28 kVp, Mo Filter) using an automatic exposure control (AEC), if available and used clinically.
4. Position the phantom on the cassette holder assembly (bucky) at a location over the image receptor that would be occupied clinically (breast). Place the compression device in contact with the phantom.
5. Using the imaging mode and kVp selected in Step 3, determine the ± density control setting (if photo-timed) or mAs (if manual) required to obtain an image optical density (O.D.) greater than 1.20, as measured in the center of the phantom image. Record this technique on the data form.
6. Load all of the mammographic imaging cassettes to be evaluated with film from the same box as used in Step 2.
7. Sequentially expose each cassette in the first half of the test group under the conditions determined in Step 5. It is useful to use lead numbers to identify the images. If AEC exposures are used, make sure that the lead numbers are not placed in the vicinity of the AEC detectors. Record the actual mAs for each exposure on the data form. It is important to ensure that the position of the phantom and AEC detector is unchanged during all exposures.
8. After the first half of the cassettes have been exposed, unload the film from the control (first) cassette and process the film. Reload, wait the appropriate time for air purge, and expose thecontrol cassette to prepare a second control film. Continue testing the cassettes from the second half of the testing group, as noted in Step 7. Reload and expose the control cassette after all test cassettes have been exposed. This will result in three control films from the one cassette, from the beginning, middle, and end of the test sequence. If possible, additional measurements of the control cassette should be made, spread throughout the measurements of the test cassettes. This will greatly improve the reliability of the results.
9. Process the exposed films in the film processor routinely used for mammographic imaging. Process the films on the same side of the processor.
10. If more than one size or type of cassette is used for mammographic imaging, repeat Steps 1 through 10 for each. The same lot of film should be used across all cassette sizes if the results are to be grouped together as the same cassette type.
11. Measure the optical density at the center of the phantom on each of the processed images and record optical density on the data form. (Identify the center by diagonals "drawn" from corner to corner across the phantom image.) If possible, take several density measurements from the area immediately surrounding the center of the phantom and average them. This will eliminate errors due to film or processing artifacts.
12. The data should be recorded on an appropriate form (see Appendix) and should be recorded in the order in which the cassettes were run. Accurate record keeping is vital to the interpretation of the test results.

Screen Speed Uniformity Data Sheet

Site / x-ray unit ABC Clinic **Processor Used** KODAK MIN-R Mammography

Screen type KODAK MIN-R EV 150

Film type KODAK MIN-R EV

Emulsion No. 304-015-14

AEC setting 0

KVp 26

MA/mAs setting _____

* Enter the data in test order, making sure that the control is run at the start, middle and end of the test. Large and small cassettes should be tested separately.

Control Cassette ID 1 **Size:** 18x24cm

	Cassette ID	Actual mAs	Density
Control Cassette	**1**	**97**	**1.85**
Test Cassette	2	95	1.85
Test Cassette	3	96	1.87
Test Cassette	4	98	1.82
Test Cassette	5	95	1.88
Test Cassette	6	96	1.89
Test Cassette	7	97	1.88
Test Cassette	8	98	1.82
Test Cassette	9	95	1.80
Test Cassette	10	95	1.80
Test Cassette	11	97	1.89
Control Cassette	**1**	**97**	**1.87**
Test Cassette	12	98	1.92
Test Cassette	13	96	1.84
Test Cassette	14	95	1.96
Test Cassette	15	97	1.89
Test Cassette	16	96	1.94
Test Cassette	17	99	1.93
Test Cassette	18	100	1.82
Test Cassette	19	95	1.92
Test Cassette	20	96	1.95
Test Cassette	21	97	1.96
Control Cassette	**1**	**99**	**1.90**

Average of controls	1.873
Standard deviation of controls	0.020548
Range of all cassettes	0.16

Data Interpretation and Analysis

Using the measured densities from the three films exposed in the control cassette, calculate the standard deviation of the control film optical densities. If the standard deviation exceeds 0.05, the variability of the x-ray exposures or film processing is excessive and the screen speed uniformity test cannot be carried out adequately under these conditions.

Corrective action should be taken to reduce this variability before assessing screen speed uniformity. If the standard deviation of the control films does not exceed 0.05, then determine the maximum and minimum optical densities from all cassettes.

> The difference between the maximum and minimum optical densities **of a single size and type** should not exceed 0.30.

Corrective action is necessary for any cassette-screen combination that does not fall within this range. If less of a difference in optical density is required, segregating cassettes into groups may be appropriate.

Suggested Performance Criteria and Corrective Action

Any individual cassette-screen(s) within a given speed group of one size or type that does not meet the above criteria should be checked to try to determine the cause of the problem. One obvious item to check is misidentification of a cassette with the type of screen(s) it contains. Also, if screens of the same speed are contained with cassettes of different manufacturers, it is possible that variations in attenuation of the cassettes may cause significant variations in film density. If after investigating, no identifiable cause for image density variation may be determined, it is reasonable to replace the cassette-screen(s) that results in optical densities outside the 0.30 O.D. range.

The Screen-Film Contact Test for Mammography

Background

The contact between the intensifying screen and x-ray film when performing mammography has a significant influence on image sharpness. Since mammographic screen-film systems have a much higher resolution than conventional general radiographic systems (16 to 20 cycles / millimeter for mammography, as opposed to 4 to 8 cycles/millimeter for conventional systems), intimacy of contact is critical in order to produce optimum quality images.

Frequency

- Semi-annually
- Prior to putting new cassettes into use

Screen-Film Contact Test Tool

Screen-film contact for mammography cassettes may be evaluated by performing a screen-film contact test. The procedure requires the use of a special test tool, which consists of a fine wire mesh made of copper, with 40 wires per inch, mounted between two thin acrylic sheets.

NOTE: *Screen-film contact test tools are commercially available from several sources. Tools with or without a one-centimeter hole are acceptable. The tool should be stored flat to prevent bowing.*

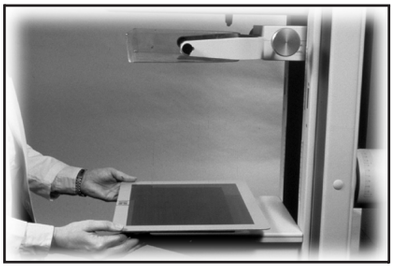
Test Procedure

1. Clean all screens and cassettes to be evaluated. Screens and cassettes must first be thoroughly cleaned since foreign matter as small as 20 micrometer will affect test results. A human hair is approximately 70 micrometer. Each cassette should have a unique identification number that will be visible on the contact radiograph. Use the following cleaning procedure:
   a. Choose a clean location to clean screens and cassettes. If working on a countertop in the darkroom used for processing mammography film, wipe the outside of cassettes and clean the countertop prior to cleaning the screens.
   b. Use a KODAK MIN-R Screen Cleaner Wipe (or moisten a second lint-free wipe with a small amount of KODAK MIN-R Screen Cleaner Solution). Clean and dry the screen. Any time 70% isopropyl alcohol is used on the screen a KODAK MIN-R Screen Cleaner Wipe or KODAK MIN-R Screen Cleaner must be used afterwards. Avoid excessive rubbing, abrasive wipes such as surgical gauze pads, pouring of any solutions directly onto the screens or into the cassettes, or using an excessive amount of any solution.
   c. Clean the inside plastic cover of the cassette (tube side panel) using a lint-free wipe that has been moistened with water. Dry the cover.

d. Inspect the screen and cassette cover for any stray particles of dust. An ultraviolet light is helpful in determining if screens and cassettes are dust free. Observe all safety precautions recommended by the ultraviolet light manufacturer, i.e., do not look directly at the light; limit the length of exposure, etc.

e. Load the cassette with film.

2. Prior to performing the test wait 5 minutes after loading to allow entrapped air to dissipate from MIN-R 2 cassettes.
3. Place each cassette on top of the image receptor (bucky with grid) or in the non-grid cassette holder with the test tool directly on top of the cassette.
4. Move the compression device close to the x-ray tube. Additional acrylic sheets may be placed on top of the compression device to achieve minimum exposure time and the required optical density.



5. Select a manual technique in order to produce an optical density between 0.70 to 0.80, measured with a spot reading densitometer over the wire mesh. The densitometer must have an aperture 2 millimeters or greater in diameter. Use 25 to 28 kVp and a reasonable exposure time. A reasonable exposure time is suggested (0.5 second, for example) to ensure a reproducible optical density on all contact radiographs. Extremely short exposure times should be avoided. Measure an area of the film near the chest wall which represents good contact (does not show increased density).
6. View the radiographs on a viewbox from a distance of at least three feet.

Evaluating Your Contact Radiographs

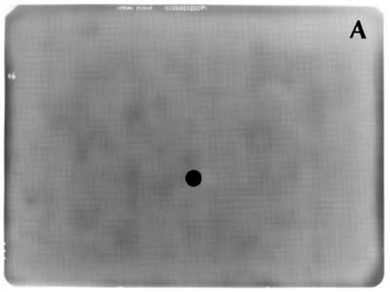
If any of your screen-film contact radiographs show areas of increased density, repeat the test after cleaning the cassettes in question a second time and waiting at least fifteen minutes after loading with film. Make sure the optical density of all contact radiographs is within the 0.70 to 0.80 range measured near the chest wall. Compare the radiographs. Cassettes with persistent large areas of increased density (greater than 1 centimeter and in the same location) should be replaced.

Contact radiographs which show multiple random areas of increased density, but all areas are less than 1 centimeter in diameter, should also be returned to service. Small areas of increased density are usually caused by minute dirt particles and will not occur in the same exact areas in comparing the first and second radiographs of a particular cassette. The use of an ultraviolet light is suggested on the insides of these cassettes after unloading to highlight any small dirt particles.

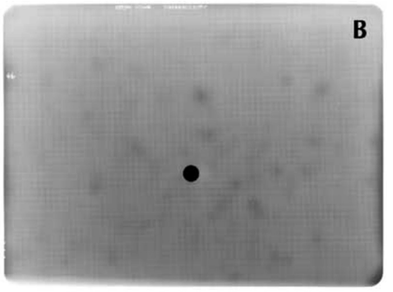
Any cassette and screen with questionable results should be cleaned and re-tested several times following the proper procedure, and the radiographs compared. Areas of increased density which shift to a different location or disappear are probably due to foreign matter or entrapped air interfering with the contact. Screens and cassettes should always be handled with reasonable care to ensure optimal mammographic image quality.

Examples

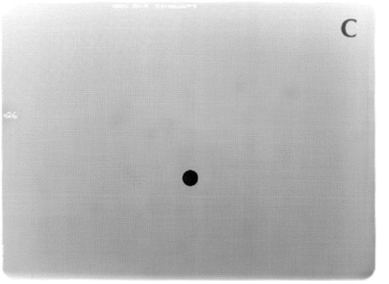
The accompanying photographs represent typical screen-film contact radiographs to assist you in evaluating your own contact radiographs. The letters "A" through "D" on the photographs denote the right hand corner of the non-chest wall side of the radiographs.



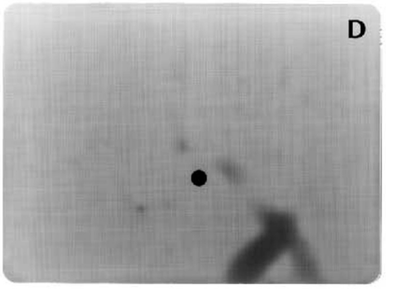
Photograph A demonstrates a diffuse increased density pattern throughout the entire image. This is representative of air trapped between the intensifying screen and film emulsion and may occur if the screen-film contact test radiograph is taken too soon after loading the cassette. The test should be repeated after waiting at least 15 minutes to obtain results that are more accurate. Photograph A also demonstrates that it is critically important to manage your Mammography cassettes during clinical use so that they have been loaded at least 15 minutes prior to patient exposure. If using improved KODAK MIN-R 2 Cassettes, exposures may be taken after waiting 5 minutes.



Photograph B corresponds to a radiograph taken after the cassette has been loaded for at least 15 minutes and shows multiple small areas of increased density. The cassette, however, was not cleaned first. Small dust specks have caused some of the areas of increased density, particularly those located to the right and slightly below the circular cut-out area. The screen and cassette should be thoroughly cleaned and then re-tested after the proper waiting period. If the contact radiographs from a cassette that has been cleaned several times still look like Photograph B, however, the cassette passes since all areas of increased density are less than 1 centimeter in diameter.



Photograph C represents the good screen-film contact test results that are possible when cassettes and the darkroom environment are very clean. In addition, the Relative Humidity of the darkroom has been controlled at approximately 45% year-round.



Photograph D represents a cassette that fails the screen-film contact test due to the areas of increased density greater than 1 centimeter in diameter, particularly at the chest wall. Cassettes that clearly fail should be replaced.

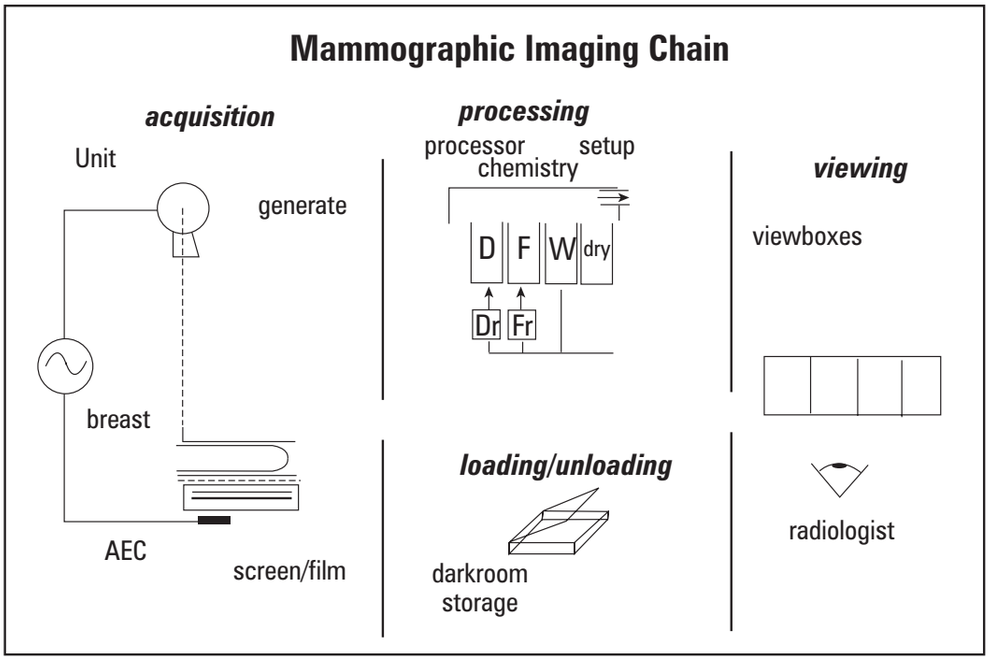
Chapter 3: Optimizing Exposure

Introduction

High quality mammographic images are a key element to a successful breast-imaging program. Image quality is dependent upon many factors that include the choice of film and screen, processing conditions, x-ray equipment capabilities and settings, positioning and compression, viewing conditions and preferences. The technologist, by positioning, exposing and processing of the images, plays a key role in successfully achieving high quality mammograms.

breast composition and thickness being imaged, so it is important to have a basic understanding of how the many technical factors affect image quality. This is true even if automated exposure modes are used.

MIN-R EV film, when properly exposed and processed, will produce the high quality images necessary for the early detection and characterization of breast cancer. Once a facility has chosen to use the MIN-R EV film system, additional factors must be considered to optimize the technique according to the many other variables that can be adjusted through the imaging chain. The factors involved and procedures that should be followed for optimizing exposure will be outlined in this section of the guide.



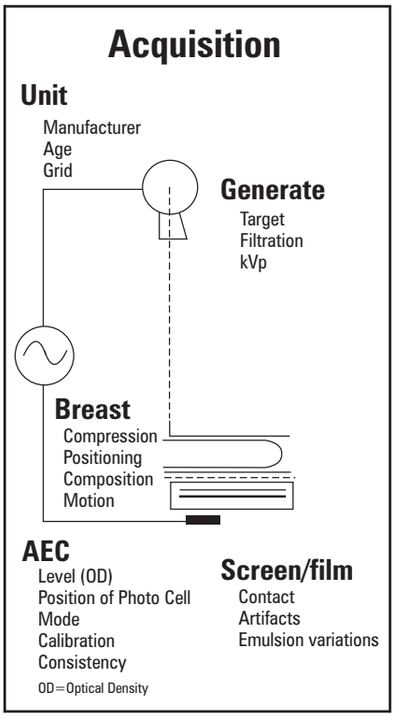
There is no current standard or single set of technical factors that are specified for optimal clinical image quality. In practice, the technical factors involved should be adjusted with the type of

Keys to success:

- **Team effort:** Ongoing consultation between radiologist, medical physicist, technologist and service engineer.
- **Documentation:** The preferred techniques should be posted in a technique chart and all technologists should follow its recommendations. Since no single technique may be adequate, some adjustment with respect to breast type and mode of operation may be necessary. Typical adjustments should be clearly identified in the technique charts. Following the technique recommendations will help ensure that the exposure selection is consistent within and between technologists.
- **Monitor:** Perform routine quality control (QC) on a regular basis. QC monitoring may allow the potential for degradation in image quality to be identified before it affects the clinical images. It is especially helpful if the facility establishes a benchmark of image quality (selected clinical and phantom images and initial process QC charts and films) that can be used for comparison on a periodic basis.

- **Review:** Periodic review by the entire team to verify optimum quality in the facility/site conditions. Sometimes factors can change which may lead to preferences for a slightly different technique, or may require adjustment to another part of the imaging chain.
- **Verify:** Although not required in most QC programs, the technologist should monitor techniques to ensure that the automatic modes match the expectations for kVp and anode/filtration-as per technique charts.

Technologists must fully understand how the x-ray unit automatic exposure control functions and the effects that kVp, different anodes and filters have on the clinical image.



Check local regulations:

Once techniques are chosen they should be checked against local state/federal, etc. regulations and/or guidance. There may not be a specific recommendation on optimal exposure; however, many recommendations or regulations might exist for some selected factors related to optimal exposure:

- **Optical density**

  A minimum optical density for the glandular tissue on mammograms of dense breast tissue may be required. For example, radiologist reviewers of clinical films for the American College of Radiology (ACR) Mammography Accreditation Program consider glandular tissue with an optical density lower than 1.0 under-exposed. It is important that all clinical and phantom images meet local state/federal, etc. regulations.

- **Dose/exposure**

  Once technique factors are selected, the exposure or dose should be measured and compared to local state/federal, etc., regulations. Although modern mammography is performed with very low radiation exposure, it may be necessary to adjust a technique to comply with local state, federal, etc. regulations.

- **Exposure time**

  ACR recommends that exposure times should be approximately 1s or less for thin or average breast (phantom) thicknesses and no longer than 3s for larger thicknesses. Exposure time should not reach back-up time (e.g. 4s) for very dense and/or thick breast. Exposures that are too short may not be reproducible or may cause grid lines; exposures that are too long risk blurring due to motion.

- **Technique charts**

  Techniques should be summarized in a chart posted at the machine, and used consistently by all technologists.

Getting started:

Before experimenting with technique selection the following validations of the imaging chain should be performed:

- **Ensure proper and consistent processing of the film.**

  For MIN-R EV Film proper processing conditions are defined in Kodak Service Bulletin 30 (January 2004). Best results will be achieved by following these processing recommendations including proper conversion and setup of the processor, and adjustment of replenishment rates according to film volume and mix. A regular quality control program for film processing will allow the processing conditions to be monitored, and adjusted when necessary as variations are identified. (See Chapter 4 of the guide for more details on processor quality control.)

- **Ensure x-ray equipment is working properly.**

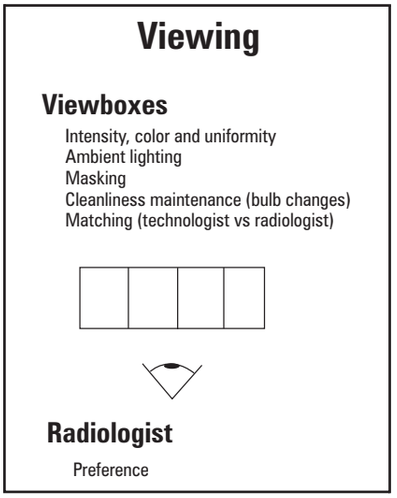
  A physics survey including kVp accuracy and automatic exposure control (AEC) performance should be performed and any recommended changes should be implemented. The x-ray equipment should be calibrated specifically to MIN-R EV film/screen combination. In addition a medical physicist and/or the x-ray equipment service representative should evaluate the x-ray unit on an on-going basis. Refer to local

regulations/ accreditation programs for required tests.

- **Ensure good positioning (especially proper compression).**

  Good positioning is essential to high quality mammography. Not only will the amount of tissue be maximized for each view, but also firm compression will be applied. Firm/taut compression reduces the potential for motion blur, reduces the scattered radiation, and reduces the range of exposure that must be recorded on the film. All of these contribute to higher image quality (especially the latter factor which allows high contrast films to be used more effectively). Many modern x-ray machines with automatic technique selection features use the compressed breast thickness in determining the technical factors for the image, making proper breast compression critical in ensuring consistent image quality.

  Mammograms are often compared with previous year(s) images. Inconsistent positioning and compression will alter the appearance of the tissue and could lead to exposure variations that make it difficult to compare images.



Evaluate viewing conditions

The viewbox is an integral part of the mammographic imaging chain. It is essential for good viewing practices to be implemented to ensure optimal interpretation. The following factors should be considered:

- Evaluate the viewboxes for cleanliness, light output, and consistency;
  - Clean the interiors and surfaces of viewboxes, replace light bulbs on a regular schedule and as needed.

  ***NOTE:** All light bulbs should be replaced whenever it is necessary to change one light bulb.*
- The intensity for all viewing panels should be matched, both within and between viewboxes.
- It is recommended that the technologist/ radiographer viewboxes match the intensity of the radiologists viewboxes used to interpret the images to aid in ensuring adequate exposure.
- There is no universal standard for viewbox luminance although the ACR suggests a minimum luminance of 3000cd/m2 in mammography.
- Use masking materials and equipment to control extraneous light.
- Control ambient light within all viewing areas.
- For additional recommendations and evaluation of the viewbox, obtain and consult the instructions in the KODAK Viewing Conditions Test Tool, KODAK publication No. M7-207, CAT No. 150 1915.

Optimizing clinical viewing conditions

- Cleanliness:
  - Remove the acrylic diffuser, clean both sides. (Replace if damaged or yellowed)
  - Clean the reflective interior of the viewbox
- Lighting:
  - Fluorescent tubes:
    - Replace every 18 to 24 months (bulbs decrease in brightness over time)
    - Replace all tubes at once (if a single tube is dimmed or flickering, all tubes should be replaced at the same time)

All tubes should be of the same type and color.

- Viewing:
  - Minimize ambient and extraneous light
    - Mask images to the edge of the dark area

Selecting Technical Factors

Contrast, noise and detail are key factors that contribute to the perception of a high quality image. Once a particular film-screen combination is chosen and a proper processing environment has been established many of the variables that can influence image quality are fixed. It remains to select the x-ray exposure factors that will make optimal use of the contrast and noise properties of the film (and as described above these should be balanced against any restrictions on the x-ray exposure parameters such as constraints due to equipment capabilities or dose requirements). The key factors relate to the spectral properties of the x-ray exposure, the exposure level and the viewing conditions.

Definition:

The radiographic contrast, or overall contrast perceived from the image is dependent upon all components of the imaging chain. Subject contrast (contrast between objects in the image as a result of differing x-ray attenuation) is influenced by the choice of x-ray spectral properties, film contrast (response of the film) which for a given image will be dependent on the exposure level to the film (film contrast varies with optical density) and the display contrast (perceived contrast as the image is viewed) influenced by the ambient light and stray light from unmasked areas of the viewbox. To optimize overall radiographic contrast the x-ray spectrum should be carefully chosen, the target film optical density of the exposure control circuit should be chosen according to the film response characteristics and these should be balanced against the viewing conditions. See Figure 7.

Subject Contrast

Spectral properties

X-rays in practical imaging systems are generated by accelerating electrons under an electric potential into a anode material inside a closed housing, or x-ray tube. The energy profile, or spectrum, will depend on the voltage applied and the anode material. In addition, filtration is used to further shape the spectral characteristics of the x-ray beam.

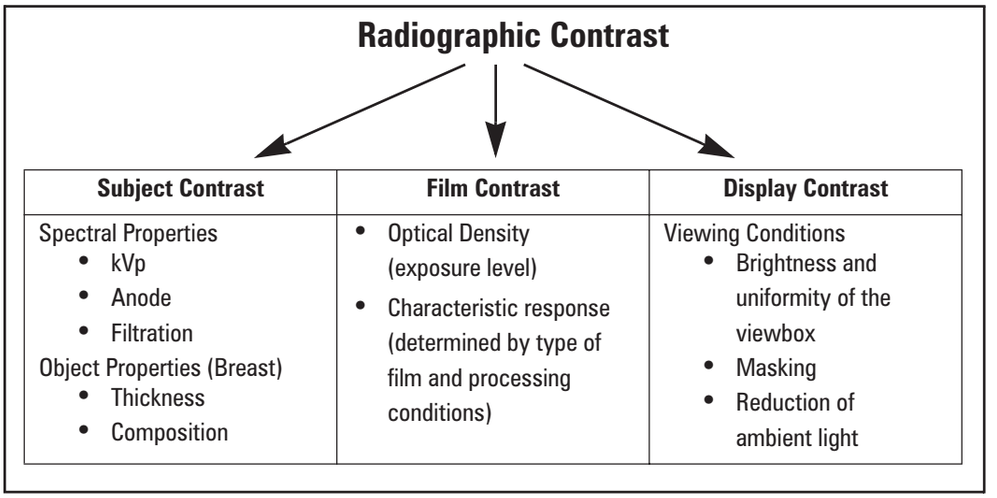


Figure 7

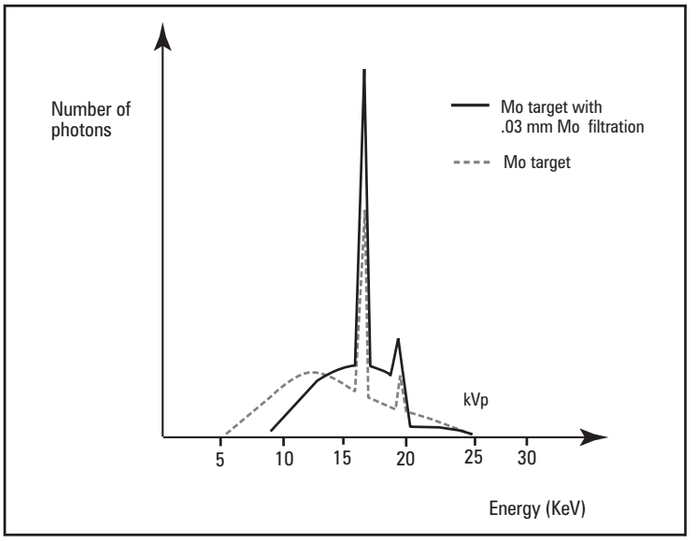


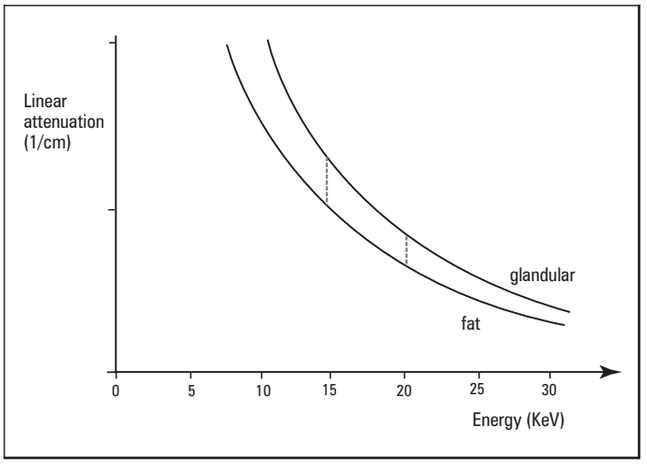
Figure 8 Representative x-ray spectra from a Mo anode x-ray tube, with and without added Mo filtration. The spectrum with filtration has been shown adjusted to produce the same light output from the screen.

A key consideration in x-ray imaging is to select an x-ray spectrum that can be practically delivered, and which will maximize the visual separation of the structures in the anatomy being examined. In breast imaging the goal is to allow the fatty tissues to be distinguished relative to the glandular tissues. The ability of these tissues to stop (attenuate) x-rays depends to a small extent on energy, and the difference in attenuation between them is slightly higher as energy is decreased. It is therefore desirable to use lower energies to image the breast. If the energy is too low, however, too many x-rays will be stopped in the breast, contributing to dose but not to the image. In addition, at lower energies, because so many x-rays are stopped in the breast, more x-rays are required in the incident beam to allow sufficient x-rays to reach and expose the film adequately, contributing to dose but also lengthening the exposure time. A longer exposure will increase the potential for motion, which will degrade the image quality. The choice of x-ray spectrum is a trade-off between the desire to increase subject contrast, but maintain a short exposure of reasonable dose.

- **kVp**

kVp, or kilovoltage peak, refers to the voltage potential used to accelerate the electrons into the anode material of the x-ray tube. As kVp is increased, the spectrum is composed of higher energy x-rays.

The traditional rules of thumb for mammographic imaging have been that the lowest kVp be selected in order to achieve the highest possible subject contrast while maintaining an acceptable dose (e.g., less than 3.0 mGy [milligrays] [300 millirads]) and an exposure time of less than 2 seconds to reduce motion. The range of 25 to 30 kVp is typically used worldwide.



Linear attenuation coefficient of fat and glandular breast tissue. The linear attenuation coefficient reflects the ability of the material to stop x-rays. The attenuation of breast glandular tissue is similar to fat, although the difference is slightly larger at lower energies. For this reason, techniques which use lower energy x-rays can improve subject contrast in the mammographic image. For more information, please consult Johns and Yaffe, 1987 PMB 32: 675-95.

- **Anode**

The spectrum of energies in an x-ray beam is primarily determined by the anode material. Many materials can be considered, but due to practical mechanical properties (such as melting point since much of the interaction in an x-ray tube produces heat) only a few select materials are used.

Molybdenum (Mo) is the most common x-ray anode in mammography. Some systems also allow rhodium (Rh) or even Tungsten (Wo). Rh will result in a spectrum of higher energy, which will reduce subject contrast, however, it has the advantage of shortening exposure time, which will reduce dose and the potential for motion. It is therefore appropriate to consider Rh or Wo for imaging very thick or dense breasts.

- **Filtration**

Filter materials are used in mammography to further shape the spectrum (especially to absorb low energy x-rays that would be absorbed in the breast and therefore contribute to dose but not to the image). Mo is the most common filtration material, although Rh is sometimes used, especially when the Rh anode is used. Rh filtration will increase the average energy of the spectrum that will reduce subject contrast, however it will shorten the exposure time, which will reduce dose and the potential for motion. It is therefore appropriate to consider Rh filtration for imaging very thick or dense breasts.

- **Exposure Control**

Modern mammography machines have a feedback mechanism of exposure control to ensure consistent darkening of the film from one exposure to the next, regardless of the composition and thickness of the breast being imaged. Obviously the success of this system depends on the consistent performance of this circuit as well as appropriate placement of the small detector that measures the exposure transmitted through the breast in each exposure. Critical to the function of this circuit is its programming or calibration to the screen-film system being used as well as to the local preferences for film darkening (target optical density).

Film Contrast

Optical Density

In most situations, for MIN-R EV film a suitable range for the target optical density is between 1.4 and 1.8. This represents a good trade-off between exposure times, viewing conditions, MIN-R EV's sensitometric characteristics, especially contrast. The higher optical densities would be suitable only for facilities with excellent viewing conditions (high luminance viewboxes, good control of ambient and extraneous light).

Display Contrast

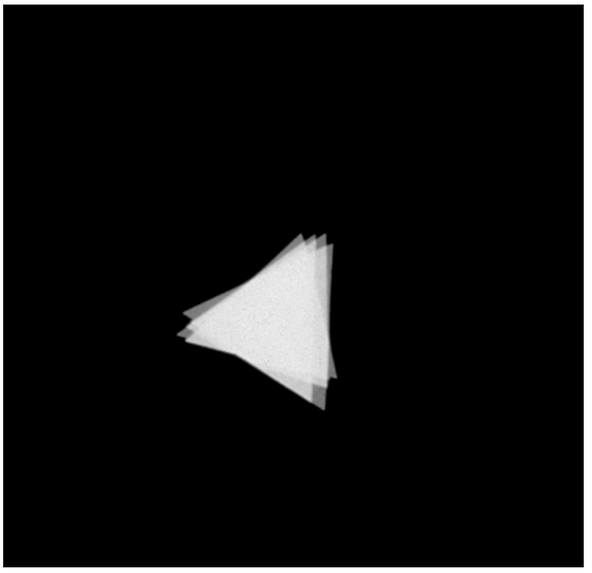
Viewing conditions

Viewing conditions are critical to ensuring that the image captured on the film can be effectively visualized. Viewboxes should be of adequate brightness and uniform across the entire viewing area. There is no universal standard for viewbox luminance although the ACR suggests a luminance of 3000 cd/m^2 in mammography. According to the discussion in the ACR Mammography Quality Control Manual (American College of Radiology, 1999), pages 292-294, this would only be sufficient to see details up to an optical density of 3.1.

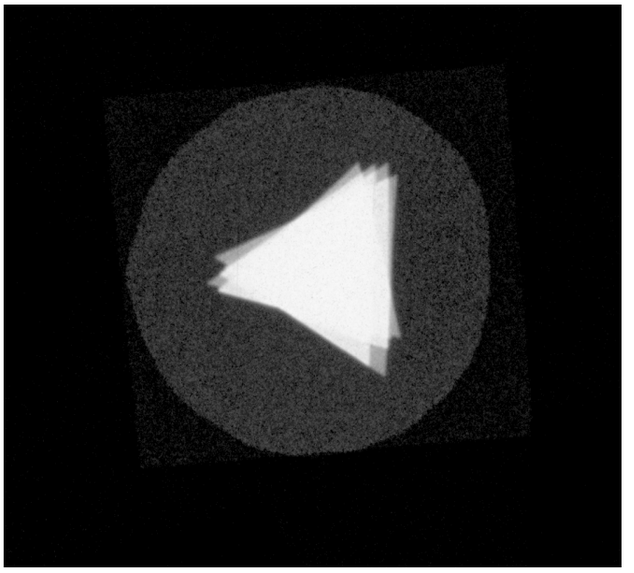
Viewbox luminance [cd/m^2]	Maximum optical density at which details can be visualized
1500	2.80
3000	3.10
7000	3.4+

A bright light would be needed to adequately see details of higher optical density-especially the fatty regions and the periphery of the breast.

In addition it is critical to reduce ambient light and stray light from unmasked areas of the viewbox. Ambient light will result in reflected light reaching the eye while stray light will also result in additional light reaching the eye, each of which will lower the perceived contrast across the image.



Unmasked and with ambient lighting.



Masked – note that under proper viewing conditions the circle is visible.

Comparison made with KODAK Viewing Conditions Test Tool, KODAK publication No. M7-207, CAT No. 150 1915.

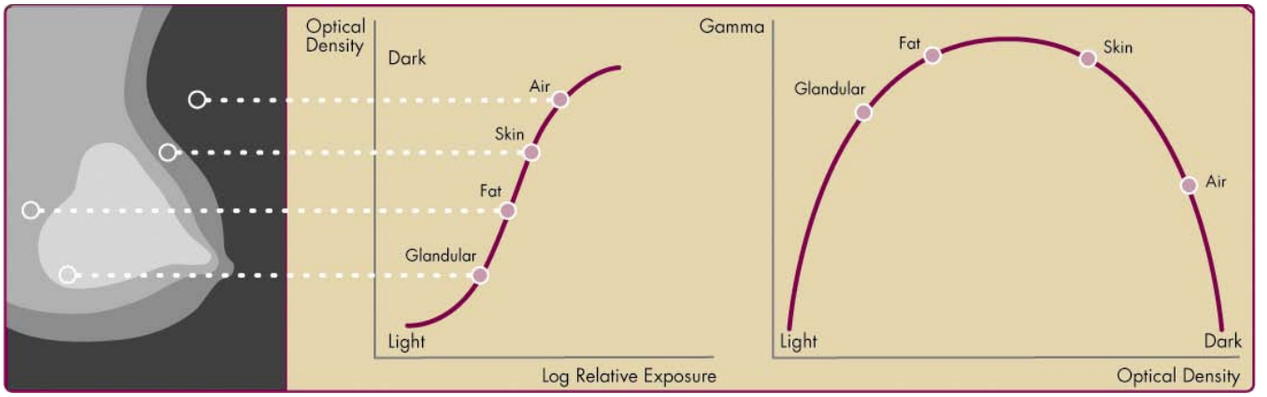
Tools/Tips:

The quality of the clinical images is the ultimate test of proper exposure technique in mammography. With no set standards, and a heavy dependence on the facility's processing and viewing conditions, as well as preferences of the radiologists, it can be difficult to optimize techniques for taking high quality mammographic images. As a follow-up to the introductory discussion (above) of the many factors that influence image quality, this section discusses several practical approaches that can aid in evaluating and selecting among the many possible technical factors.

Film response curves: characteristic curves and contrast-optical density (gamma) plots

In screen-film mammography the x-ray pattern is recorded on the film. Therefore, the response of the film, in terms of the way it translates x-ray exposure into optical density is critical to understanding the image quality. The response of the film is one of several important visual factors, which contribute to a preference of one film over another (film response is not the only factor, to name just a few others, noise and detail capabilities of the film are also important factors). MIN-R EV Film has been carefully designed to achieve optimum contrast response over the entire range that the film is responsive to x-rays. With regards to the present discussion on optimizing image quality, however, the film response can also be used to provide some guidance.

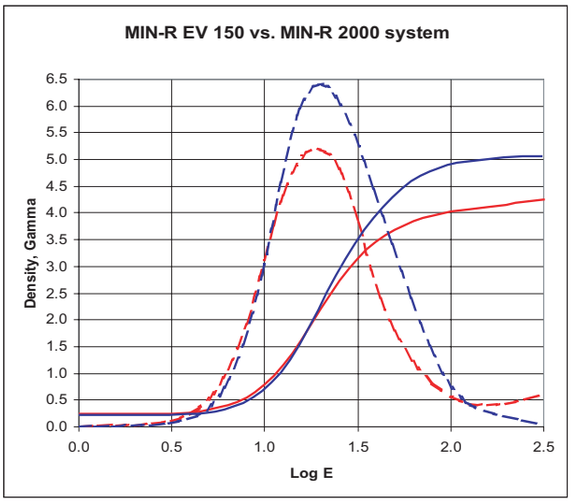
The characteristic curve (also known as the Hurter and Driffield (H&D) curve) is a method for displaying the response of the film. This curve plots the optical density in a processed film against the exposure needed to achieve that density. Another graphical approach to representing film response is to plot the contrast of the film at each optical density the film can achieve. This is known as a contrast-optical density plot, or gamma plot, after the Greek letter, which is used to represent contrast. Both curves can be constructed using experimental techniques known as sensitometry.

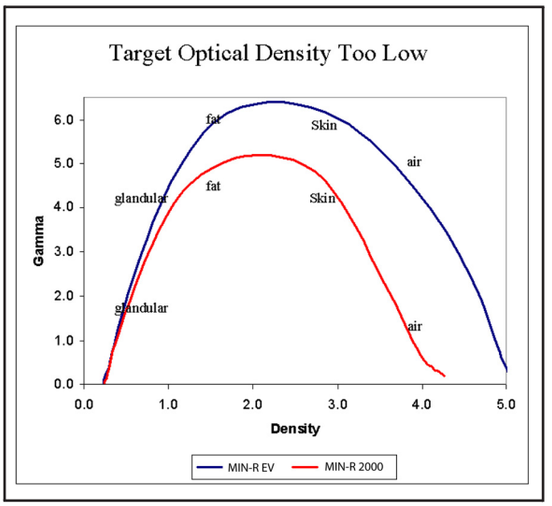


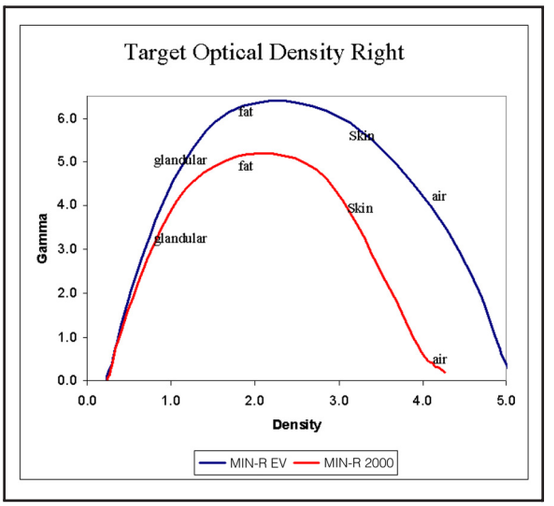
Kodak uses inverse-square sensitometry to measure the specific performance of x-ray films including the characteristic curve, and the contrast-optical density curve (gamma plot). In inverse-square sensitometry the principal that exposure decreases according to the inverse of the square of the distance from the source is used to produce a response at various exposures. A mammography screen and x-ray exposure is used to generate the film response in this configuration. The characteristic curve and the contrast/optical density curves (gamma plot) from an emulsion of KODAK MIN-R EV Film shown below were generated by inverse square sensitometry and processed according to Kodak recommendations.

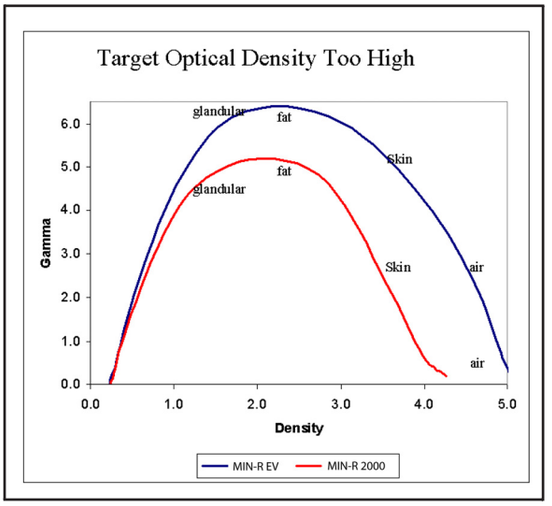
Practical Application of Film Curves

The exposure to ensure high quality images must be selected so that the target optical density of the AEC is in a range that the film is responding to x-rays. It is tempting to select the target optical density at the peak of the contrast/optical density curve, where the film is the most responsive to changes in exposure. In this example an optical density of about 2.0 is approximately mid-way through the range that the film is responsive and is near the peak of the contrast-optical density curve. Note, however, that the contrast/optical density curve in this example demonstrates highest contrast over a range of optical densities (1.5-2.2). Target optical density must take in to consideration that the breast is not always homogeneous i.e., the breast is composed of fat and fibrous tissue in different proportions. Taking into consideration the composition and thickness changes in the breast, there are strong motivations to use an optical density at the lower part of this range. A target optical density that is too high will result in over-penetration of the fatty portions of the breast and the peripheral (skin) regions, where the thinning of the breast results in an overall darkening of the image. Selection of a target optical density in the range of 1.4-1.8 will in most cases allow for the glandular and the fatty portions of the breast to be imaged with adequate contras and penetration.









Taking factors other than the film response into consideration, there are additional reasons to choose an optical density lower than the peak of the contrast-optical density curve:

- **VIEWING:** At higher densities, less light is transmitted through the film. It is necessary, therefore, when using higher optical density to use a brighter viewbox or bright spot lamp in order to ensure that there is enough light for the observer to interpret the image. If ambient lighting is prevalent, then reflected light and glare will increase the light reaching the eye and will reduce the perceived contrast. Similarly if the images are not properly masked, the extraneous light reaching the eye will reduce the perceived contrast. These effects can be substantial and will result in the whites not being perceived as white and the image will appear less "sharp".
- **TONE:** At higher densities, the tone of the image will appear "warmer" or less blue. Optical density is a major factor influencing the perceived tone of an image. At higher densities the shape (morphology) and distribution of the developed silver cause the image to be perceived to be less blue.
- **NOISE:** Film grain increases slightly with MIN-R EV as optical densities increase, quantum mottle will be the major cause of noise at higher optical densities. Raising the optical density will result in more of the image (especially the periphery) to be at higher optical densities. Unless proper precautions are taken to insure excellent viewing conditions, this reduces a person's ability to visualize structure in all parts of an image.

- **DOSE:** At higher optical densities, the technical factors typically mean longer exposure or higher kVp. A longer exposure increases the potential that motion blur will degrade the image. At higher kVp the subject contrast is reduced, which may low the overall contrast in the image.

The contrast/optical density curves shown on the previous page are representative of the response that should be expected at a given facility when MIN-R EV film is processed in an optimized processing environment following Kodak recommendations. If a more detailed analysis is desired according to the specific processing conditions of a given facility, then simulated light sensitometry can be used. In simulated-light sensitometry, the characteristic curve is created by exposing a film with a sensitometer (a device which simulates the light that the film would get from the x-ray screen in a typical x-ray procedure in a series, or "steps" of increasing exposure) and plotting the optical density for each exposure step as measured from the processed film with a densitometer (a device which can measure the optical density of small areas of the film). The data from the characteristic curve can also be reformatted to plot the contrast optical density curve, or gamma plot. Gamma at the density of a given step would be approximated as the slope in the characteristic curve over the steps immediately below and above the given step. An entire gamma curve can be constructed by repeating the calculation for each optical density step. When calculated in this way, the gamma is only an approximation of the true response at each optical density, but in many cases this would be adequate to examine the gross details of contrast behavior.

(Procedures for calculating the gamma manually are described in detail in: *Hendrick R.E. and Berns E.A. Optimizing the Selection of Film and Film Processing. In: Advances in Film Processing Systems Technology and Quality Control in Medical Imaging, edited by A.G. Haus (Medical Physics Publishing, Madison, WI, 2001) 115-127.)* Alternatively, many scanning densitometers have the capability to generate the data for gamma plots automatically. Such devices typically provide the gamma value at 0.10 increments of optical density. *(The sensitometer and densitometer are very effective tools for use in film quality control programs, to ensure consistent day to day processing of the film. See chapter 4 of this guide for more details on process quality control.)*

It is important to remember when calculating and interpreting characteristic curves or gamma plots using the response measured from a sensitometer that the light from the sensitometer is simulated screen light, not actual screen light. Simulated light sensitometry is adequate for monitoring film processing performance, but since it is not screen light, it is only an approximation of the film response.

The use of the characteristic curve and contrast-optical density curves provides important theoretical insight into the optical densities that should be used to optimize image quality. If the film were only used to capture the image, this would be adequate to optimize contrast in the image. It is important to remember, however, that the film also acts in combination with the view box as the display device. The display of the images must be carefully considered to optimize the simultaneous roles as recording and display device. The next section describes a more practical approach where actual images are used to evaluate the optical density to which images should be exposed. The use of images takes into consideration both recording of the image, as well as the viewing and display preferences of the observer.

For more discussion on film gamma as it applies to optimizing techniques in screen-film mammography consider the following publications of Dr. Ed Hendrick and Mr. Eric Berns:

- Hendrick R.E. and Berns E.A. *Optimizing Mammographic Techniques. In: 1999 Syllabus Categorical Course in Diagnostic Radiology Physics: Physical Aspects of Breast Imaging – Current and Future Considerations,*. edited by A.G. Haus and M.J. Yaffe (Radiologic Society of North America Publishing, Oak Brook IL, 1999) 79-89
- Hendrick R.E. and Berns E.A. *Optimizing Techniques in Screen-Film Mammography. Radiologic Clinics of North America Vol 38* No. 4:701-718, July 2000
- Hendrick R.E. and Berns E.A. *Optimizing the Selection of Film and Film Processing. In: Advances in Film Processing Systems Technology and Quality Control in Medical Imaging,* edited by A.G. Haus (Medical Physics Publishing, Madison, WI, 2001) 115-127.

Optical density series

Procedure #1: for assessing the effect of optical density on image quality

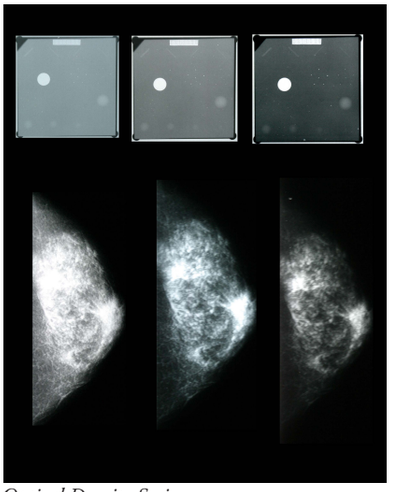
The following is a procedure that can be used to assess the effect of optical density on image quality. The procedure will produce phantom images that can be evaluated to assess image quality as the optical density is changed. MIN-R EV film will produce high quality images over a range of optical densities, and the

choice at a given facility will be heavily dependent on the viewing conditions and the preferences of the radiologists. This technique might be helpful in determining an optical density range to confirm with clinical images.

1. Assemble the tools which will be needed:
   - Mammographic phantom (e.g., phantom that adheres to the ACR mammographic accreditation phantom and/or anthropomorphic phantom).
   - Mammographic cassette of the type used clinically (ideally, the same cassette should be used for all exposures).
   - Fresh box of MIN-R EV mammography film (all images must be made using the same emulsion).
   - Spot reading densitometer.
   - Prepare a mask for the images by exposing a 35 x 43 cm film to light, processing the film and cutting the mask and films to accommodate the images.

   NOTE: *Mask to the edge of wax insert if using the ACR accreditation phantom.*
2. For each exposure, in the darkroom under appropriate safelighting, load a sheet of film into a clean mammographic cassette. Wait at least 5 minutes prior to each exposure.
3. Prepare to make the first exposure:
   - Place the cassette into the moving grid cassette holder of the mammographic unit.
   - Position the phantom on top of the grid.
   - Lower the compression device until it contacts the top of the phantom. Ensure that all the images are taken with the same compression, preferably disabling the compression release if possible.
   - Position the photoreceptor so it is centered underneath the phantom.
   - The maximum exposure time of any image should not exceed some pre-determined value, such as 2 seconds.

   NOTE: *The kVp and filtration should be fixed between all images at settings typically used for clinical images. The next section describes a procedure for evaluating kVp and filtration.*
4. Expose a series of phantom images using automatic exposure control in a fixed kVp mode, e.g., 28, and varying the density control setting. For example, make exposures using the -2, -1, 0, +1, and +2 settings on the density control. Aim for the background optical density of all phantom images to range from a minimum of 1.40 to approximately 2.2. Use the densitometer to check the actual optical density in the center of each image.
5. Place the masked phantom images sequentially, labeled with the optical density used, on an illuminated viewbox used for mammography in a darkened room and examine the images.
6. Identify the image that shows the greatest amount of information (details). The optical density of the preferred image may indicate the optical density that should be used clinically.
7. Verify that the selected optical density produces adequate contrast in clinical images by making several exposures with the settings that produce that optical density in the phantom. It may be necessary to increase the optical density if glandular tissue is under-penetrated, or lower the optical density, if fatty tissue is overexposed.



Optical Density Series

Spectral changes (kVp series)

Procedure #2: for assessing the effect of varying kVp on image quality:

The following is a procedure that can be used to assess the effect of kVp on image quality. The procedure will produce phantom images that can be used to evaluate image quality as kVp is changed. It is expected that lower kVp will produce the best contrast – however, in some circumstances it may be desirable to use higher kVp to lower dose, or comply with exposure regulations. This technique might be helpful in determining how much kVp can be increased before image quality is adversely affected.

(Filtration will also change the energy spectrum and hence impact the contrast in the image. The following procedure can be adapted to explore the impact of filtration changes on image quality by adjusting the filtration between exposures at a given kVp.)

(The following procedure assumes satisfactory kVp accuracy and reproducibility.)

1. Assemble the tools which will be needed:

- Mammographic phantom (e.g., phantom that adheres to the ACR mammographic accreditation phantom and/or anthropomorphic phantom).
- Mammographic cassette of the type used clinically (ideally, the same cassette should be used for all exposures).
- Fresh box of MIN-R EV mammography film (all images must be made using the same emulsion).
- Spot reading densitometer.
- Prepare a mask for the images by exposing a 35 x 43 cm film to light, processing the film and cutting the mask and films to accommodate the images.

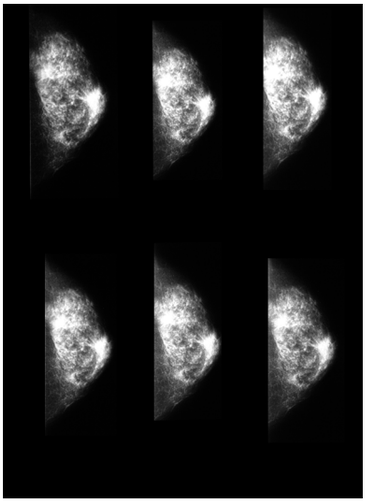
  NOTE: *Mask to the edge of wax insert if using the ACR accreditation phantom.*

2. For each exposure, in the darkroom under appropriate safelighting, load a sheet of film into a clean mammographic cassette. Wait at least 5 minutes prior to each exposure.
3. Prepare to make the first exposure:

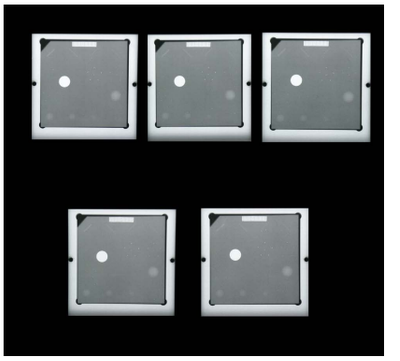
- Place the cassette into the moving grid cassette holder of the mammographic unit.
- Position the phantom on top of the grid.
- Lower the compression device until it contacts the top of the phantom. Ensure that all the images are taken with the same compression, preferably disabling the compression release if possible.
- Position the photoreceptor so it is centered underneath the phantom.
- The maximum exposure time of any image should not exceed some pre-determined value, such as 2 seconds.

  NOTE: *The target optical density should be as typically used clinically. Each image in the following series should be within 0.05 of the target optical density.*

4. Expose a series of phantom images in an auto-time mode of the AEC, varying the kVp by one kVp increments, from the lowest kVp to the highest (i.e., 25-30 kVp).
5. Place the masked phantom images sequentially, labeled with the kVp, used on an illuminated viewbox used for mammography in a darkened room and view.
6. Identify the image that shows the greatest amount of information (details). The kVp and optical density of the preferred image may indicate the best technique for the phantom on the specific piece of mammographic x-ray equipment used.
7. Verify that the selected kVp produces adequate contrast in clinical images by making several clinical exposures at that kVp setting. If more contrast is desired consider lowering the kVp. If less contrast is desired or could be tolerated, the kVp could be lowered.



kVp series: RMI 165 anthropomorphic phantom



kVp series: RMI 156 phantom

NOTE: *this procedure can also be used to evaluate the affect of filtration changes on image quality. For a selected kVp an additional image in which a second filtration option is selected can be taken and compared to the image with the filtration setting of the reference technique.*

DISCUSSION

(Review of the optical density and kVp series):

- The above procedures can be a guide to selecting the optimal kVp according to the specific phantom used, which simulates one specific breast thickness and type only. The facility should establish an optimal kVp range for different breast thicknesses and densities. In particular, the use of one kVp for all breast types is not recommended.
- Study the images to assess the impact of changing kVp and optical density has on contrast. Optical density can have a significant affect on image contrast. The higher contrast of MIN-R EV may make it possible to utilize higher kVps than those used previously.
  - Phantoms comparing Mo to Rh can also be useful to assess the impact on contrast. Please reference Hendrick R, Berns E., *Optimizing Mammographic Techniques*, RSNA Categorical Course in Breast Imaging, 1999; 79-89, for a discussion of some of the benefits that may be achieved by using the Rhodium filter.

> ***NOTE:*** *The procedures are meant as a guide and starting point only for determining technique selection. Clinical images of various different breast types and thicknesses must be assessed to ensure that the radiologist preferences for contrast and optical density are met.*

Once technical factors are selected for clinical imaging, it is recommended that a record be kept of the patient identification numbers of the optimum image quality of various breast types. Examples of a fatty, semiglandular and glandular breast with ideal contrast and optical density should be noted to use as reference in ongoing clinical review. These images would be considered the benchmark.

The initial phantom image using the factors used clinically should also be kept as the benchmark phantom image.

Putting it together

Technique Charts

It will be necessary to generate technique charts for each piece of equipment. Technique charts, generally used with automatic exposure control where the kVp is selected by the technologist/operator, should indicate how the kVp is altered from that used on the mammographic phantom as the breast thickness and density changes. Slightly lower kVp should be used for breasts compressed thinner than the phantom; slightly higher kVp should be used for breasts compressed thicker than the phantom. Technique charts should also include reference to different anode and filter combinations if used for different breast thicknesses and/or density. In all cases, the kVp selected for any particular exposure should allow that exposure to be completed without exceeding the maximum desirable length of time.

In many circumstances, regulatory requirements stipulate that technique charts be posted on each piece of equipment. Note that even if using a fully automatic exposure control system, technique charts showing the appropriate program(s) should also be posted on each piece of equipment. (Refer to the manufacturer of the equipment as to their recommendations for choosing the correct program for specific screen-film combinations and technical parameters. It is very important that all types of mammographic x-ray equipment be initially calibrated for a new screen-film combination.)

All technologists/operators should be trained on the use of the technique charts and on any differences associated with the use of a different screen-film combination. It is important to note that as technology changes occur, different practices may be not only necessary but absolutely critical to obtain optimal image quality. In particular, higher kVp or different technical parameters than used previously with lower contrast screen-film combinations may be appropriate.

- Each mammographic x-ray unit should be evaluated.
- Consultation with the medical physicist or governmental agency regarding local/national dose regulations is suggested before making any permanent exposure technique changes.
- *The preferred kVp (and optical density) will be heavily influenced by the light output and viewing conditions where the assessment took place.*

AEC detector position

The automatic exposure control system is governed by the measured response of a small detector placed beneath the breast during imaging. It is the objective of this system to ensure adequate darkening of the film, to achieve the desired optical densities in the final processed image. Due to the small size of this detector, the feedback on exposure is limited to the small sample of tissue located immediately above the position of the detector. If the detector is located under fatty tissue only, then the exposure will terminate prematurely, resulting in under-exposure of the dense fibro-glandular tissue of the breast. It is critical then to ensure good placement of the sensor.

There are several possible positions for the AEC sensor (the exact location depends on the specific x-ray unit being used), however, there is little guidance to determining the best location within a breast before the image is taken. The first guide is that the AEC sensor should be located within the breast, so in the positioning of small breasts, an AEC sensor position close to the chest wall is the only practical approach. In larger breasts, more of the AEC sensor positions are within the area of the breast, so it can be difficult to locate the sensor. Sometimes, when prior images are available, it is possible to estimate the distribution of the tissue in the breast, and therefore place the AEC sensor under the most glandular area. Also in a well-positioned breast the retromammary fat will be pulled onto the image and will be close to the chest wall, so this position should not be chosen in breasts that are large enough to extend to the more distant sensor positions.

Because of the variation in sensor location, even when all other factors are optimized, it will be sometimes necessary to repeat an exposure to ensure adequate penetration of all tissues in the breast. If the desire is to increase the penetration of the dense tissues in the breast, then the exposure should be increased in the repeat exam i.e. raise the density setting of the automatic exposure control circuit. Conversely, if the image appears too dark, especially in the fatty parts of the image, consider lowering the density control setting to lower the exposure in the repeat image. The density control setting is discussed in more detail in the next section.

Density control setting.

The density setting on the mammography machine plays an important role in ensuring high quality mammography images. It is expected that there will be slight differences in the film speed between each batch (emulsion) of film. As a result the exposure may need to be adjusted slightly when a new emulsion is put into use, to ensure the appropriate optical densities are achieved. To determine if an adjustment of the density setting is required, a phantom image from the emulsion in prior use should be compared to a phantom image from the emulsion to be put into use. If the image from the new emulsion is darker than the density setting should be lowered, conversely if the new emulsion is lighter, the density setting should be raised. It is important to ensure that the test conditions be as similar as possible between the two measurements (the phantom should be placed in the identical location in the image, the AEC should be positioned in the identical location, the same exposure mode should be used, and the resulting images should be measured for optical density in the identical location). It is also important to ensure that the processor quality control is stable to be sure that any adjustment of the density setting will be due only to the change in emulsion, otherwise image variability will be the result. (Please refer to the split phantom test discussion in the Troubleshooting section.)

The adjustment of the density setting between emulsions of film is discussed in many quality control programs. For example, see page 185 in the 1999 revision of the American College of Radiology (ACR) quality control manual for more details.

When using a mammographic film that is high in contrast, such as KODAK MIN-R EV Film, the window for achieving a properly exposed mammographic image is smaller, i.e., it has reduced exposure latitude and care must be taken in mammographic technique. If a given image is too dark (over-exposed) or too light (under-exposed) then the density control setting can be used to adjust the exposure slightly in a repeat image. Lowering the density setting will reduce the exposure up to ~15% (depending on the model and calibration of the x-ray unit) and will lighten an image that is too dark. Raising the density setting will increase the exposure and will darken an image that is too light.

Quick Reference Guide

To raise contrast

- Lower kVp
- Select Mo anode and Mo filtration
- Optimize film processing
- Select KODAK X-OMAT EX II Developer
- Adjust optical density within the range (1.5-1.8)

To lower contrast

- Raise kVp
- Select Rh filtration
- Select Rh or Wo anode with Rh filtration
- Select KODAK RP X-OMAT Developer (versus KODAK X-OMAT EX II)
- **Do not alter processing to lower contrast**

To lower noise

- Lower kVp
- Select Mo anode and Mo filtration
- Raise optical density (i.e. increase exposure time). Do not exceed 2.0 optical density on the accreditation phantom.
- Select KODAK RP X-OMAT developer over EX II developer
- Use a slower screen, e.g., MIN-R EV 150 vs. MIN-R EV 190

To lower dose (may increase perception of noise)

- Raise kVp
- Use faster screen (e.g. MIN-R EV 190 screen vs. MIN-R EV 150 screen)
- Select Rh filtration
- Select Rh or Wo anode and Rh filtration
- Lower optical density

Keys to success

- Proper processing set up
- X-ray unit calibrated to MIN-R EV screen-film system
- Optical density optimized
- Proper viewing conditions
- Team communication

These recommendations should be taken as guidelines only. The radiologist/medical practitioner is responsible for interpreting the mammogram. They must be consulted when MIN-R EV techniques are established.

Chapter 4: Quality Control (QC)

Emulsion Number Log
KODAK MIN-R EV Film

Date	Emulsion #	Size	QC	Comments
3/14/04	311-15-12	18 x 24	✓	
3/14/04	311-16-11	24 x 30		
4/15/04	312-13-12	18 x 24		
5/4/04	313-31-14	24 x 30		
5/18/04	311-18-12	18 x 24	✓	Re-established QC

Some simple but very effective tools/instructions are available for troubleshooting the processor and KODAK MIN-R EV Film System. They include:

- Emulsion Number Log
- Establishing Aims
- Monitoring [Quality Control]
- Film Crossover Procedure
- Retaining the developer solution

Emulsion Number Log

Film manufacturers designate each box of x-ray film with a multiple-digit emulsion number. This number provides important information such as which particular emulsion batch was used as well as which roll it came from, and the specific part (slit) of the roll.

Keeping track of the emulsion number of the film used for processor quality control is done for processor quality control. It is also extremely advantageous to keep track of the complete emulsion numbers of all film used clinically. Doing so allows film manufacturers to make comparisons in speed, contrast, D-max, etc., between current clinical images and images taken one or more years previously. Such comparisons may assist in troubleshooting image quality concerns. (Please refer to the Split Film Phantom procedure on page 90.)

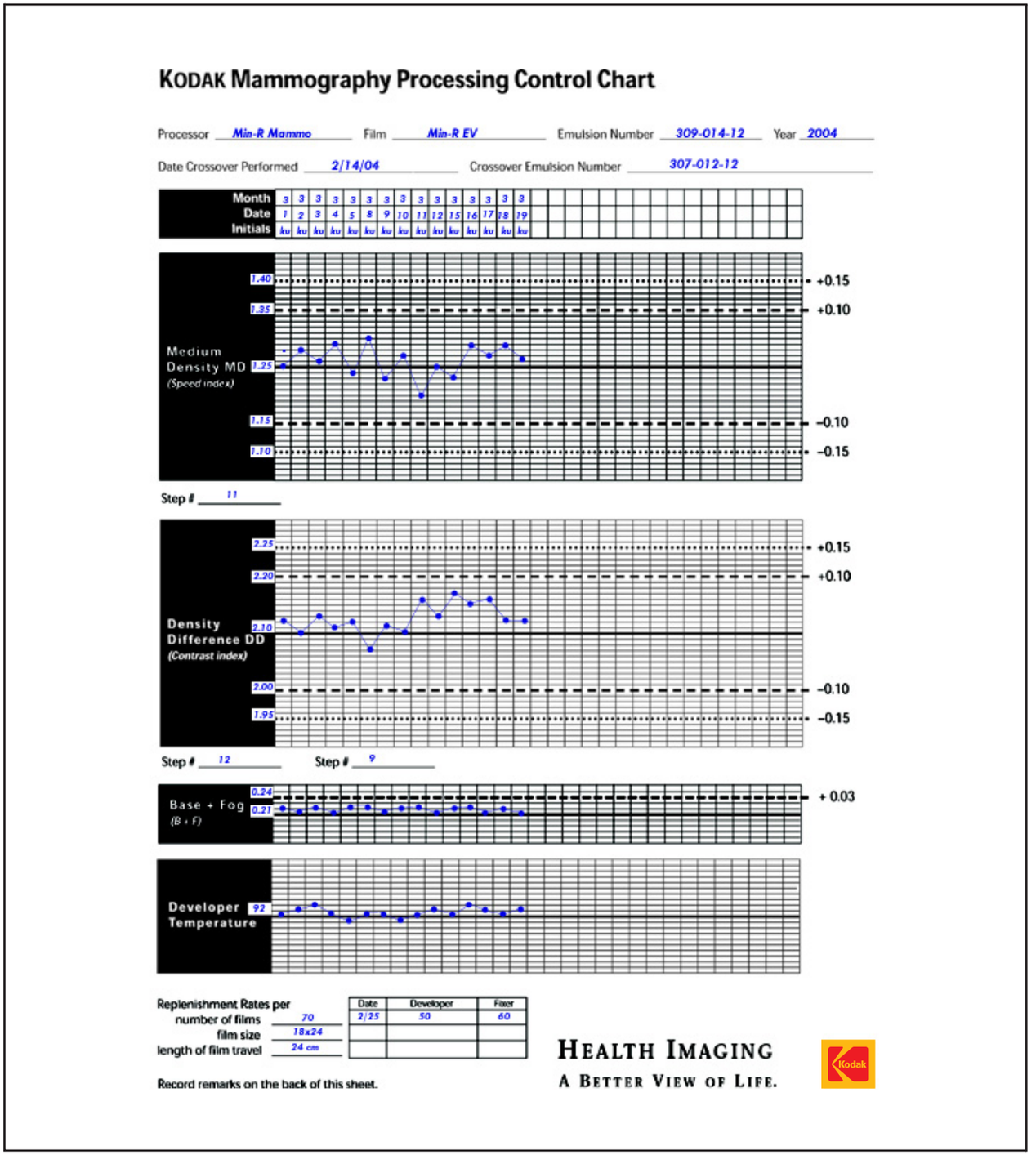
The easiest way to retain this information is to start an emulsion number log. The log should be posted in a convenient area and contain the following information:

- Type of film
- Date the box of film was opened
- Film size
- Complete emulsion number
- Any other comments, such as which emulsions were used for processor QC or phantom images. Refer to the example above of an emulsion number log. Every time a box of film with a different emulsion number is opened, a new entry should be made in the log.

Processor QC

Introduction: What is Processor QC?

Processor QC is a method for daily monitoring of the performance and consistency of the processor and chemistry. Small changes in the speed and contrast are expected. These levels will vary due to the release of chemicals during the development process, changes in film volume, quality of solutions, etc.



Aim values for speed, contrast and base + fog can be used to monitor the processing environment and ensure that adequate processing is being maintained. Processor QC is a means of not only identifying when the processor chemistry is out of control but to help identify trends and take corrective action before the processor is out of limits and cannot be used to process mammograms.

Establishing aims

Please note that MIN-R EV film should be exposed with the primary emulsion side down (facing the light source of the sensitometer). When making the exposure it is not necessary to use a dual sided sensitometer setting. For further reference, please refer to the *KODAK MIN-R EV Film Conversion Instructions and Processing Recommendations* (found in the appendix of this guide).

Process Control Procedure for Mammographic Processors

Items Needed

- Sensitometer with 21 density steps.
- Densitometer.
- Thermometer (not mercury) with accuracy of ± 0.50°F (±0.30°C).
- Fresh box of 18 x 24cm film, the same as that used for mammography.
- Control charts such as the KODAK Mammography Processing Control Chart which may be downloaded from the Kodak web site: www.kodak.com/go/mammo.

Establishing the Baseline

1. Ensure that:
   - the processor is thoroughly clean and functioning properly
   - the processor is filled with properly mixed fresh chemicals
   - the proper amount of developer starter has been added
   - the proper developer temperature and replenishment rates have been set.
2. Set aside a fresh box of 18 x 24 cm film that is used for mammography. Designate it as your "QC" film and record the complete emulsion number on the control chart.
3. Set the sensitometer for the appropriate film spectral sensitivity (green) and for single-emulsion film.
4. On five (5) consecutive days, expose a sensitometric strip using film from the "QC" box; process immediately. Note that:
   1. the processor must be at the right temperature
   2. the probe of the thermometer should be placed consistently in the same area on the non-drive side of the processor developer tank
   3. single-emulsion film must be inserted into the sensitometer so the emulsion side faces the light-exposing source
   4. the sensitometric strip must be consistently fed into the processor so that the less-exposed end is fed first.
   5. On the fifth day, use the densitometer to read the 21 density steps on each processed film.

      NOTE: *Take the reading from the middle of each step.*
   6. Average the values of the 21 steps for the five days.

Determining Mid-Density (MD)

1. Determine which step has an average density closest to 1.20. Designate this step as the mid-density (MD) step for all future MD determinations and record the step number on the chart.
2. Write the average MD value on the middle line.

Determining Density Difference (DD)

1. Select the step with the average density closest to 2.20.
2. Select the step with the average density closest to, but not less than, 0.45.
3. Subtract the density value determined in step 2 from the density value determined in step 1. This value will be the density difference (DD).
4. Designate the two steps as those to be used for all future DD determinations and record the step numbers on the chart. Write the average DD value on the middle line.

Determining Base + Fog

1. The five-day average of the least-exposed step (usually the first step) determines the Base + Fog of the film. (Any clear area of the film may also be used to determine Base + Fog.)
2. Write the average Base + Fog value on the middle line.

Developer Temperature

1. On the middle line, write the developer temperature recommended by the film manufacturer for your:
   - type of film
   - developer (chemicals)
   - processor
   - length of developer immersion time.

Establishing Operating Limits

1. The preferred mammography MD and DD operating limits are ± 0.10. The maximum outermost limits are ± 0.15.
2. Add 0.10 and 0.15 to the values on the middle line for MD and DD; write the preferred and maximum upper limits on the control chart.
3. Subtract 0.10 and 0.15 from the values on the middle line for MD and DD; write the preferred and maximum lower limits on the control chart.
4. Add 0.03 to the value on the middle line for Base + Fog; write the upper limit on the control chart. (There is no lower limit for Base + Fog.)

Daily Processor Quality Control

1. Expose and process a sensitometric strip each morning that mammography films will be processed.

2. Use the densitometer to read the values for MD, DD and Base + Fog, using the same steps recorded on the control chart.
3. Plot the MD, DD, Base + Fog, and measured temperature values on the control chart.
4. Evaluate the results and make any necessary adjustments before processing any films.

Evaluating The Control Chart

1. Points that are plotted on the control chart for MD and DD that are within the ±0.10 control limits should be considered normal process variations.
2. If any points are plotted on the control chart for MD and DD between ± 0.10 and ± 0.15, expose and process another sensitometric strip for comparison. Mammography films may be processed. The processor should be closely monitored to make certain that the outermost limits are not exceeded.
3. If any plotted points on the control chart for MD and DD reach or exceed ± 0.15, expose and process another sensitometric strip for comparison. If the same results are obtained, no mammography films may be processed until the cause is determined and corrected. Plot the results obtained after the process has been brought back "in control." Note the action(s) taken to achieve this in the "Remarks" section on the control chart.
4. Any points plotted for Base + Fog that are within 0.03 are considered to be normal process variations; any points plotted for Base + Fog that exceed + 0.03 require immediate analysis.
5. The developer temperature should remain as close as possible to the temperature recommended by the film manufacturer; it should not vary by more than ±0.50°F (±0.30°C).
6. A trend exists if a series of consecutive points (three or more) progress steadily upward or downward. Such a trend may be a shift taking place slowly and visibly with respect to time. Monitor the processor closely.
7. Trends or gross fluctuations should be noted and evaluated. If necessary, appropriate action should be taken.

The "Remarks" section of the control chart should be used to note reasons for fluctuations such as routine preventive maintenance, fresh chemicals or developer starter added, etc.

Final Comments

It is recommended that a processor maintenance log be kept for each processor to record all service on the unit. This log can be used to correlate processor service with processor performance. The calibration of the sensitometer, densitometer and thermometer should be checked periodically according to the recommendations, where available, of the manufacturer. The Kodak Mammography Processing Control Chart may be used in various ways to monitor processor performance. For example, a new chart may be used for each month or information may be plotted continuously and a new chart started every 31 days.

Prior to establishing processor control limits, it is imperative that the processor be set up correctly following Service Bulletin No. 30 (enclosed) and the *Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film* (found in the Appendix of this guide). Clinical images must also be acceptable. (For further reference, see the Optimizing Exposure Technique section of this guide).

The processor will season to an equilibrium. The "seasoning effect" (the change in QC values between a fresh developer start up and the developer once it has reached equilibrium) is the rationale for averaging qc strips from multiple days to establish a baseline.

Seasoning is dependent on a variety of factors: chemistry (please refer to the Chemistry section of this guide), replenishment rates, film optical density and the area of exposed film.

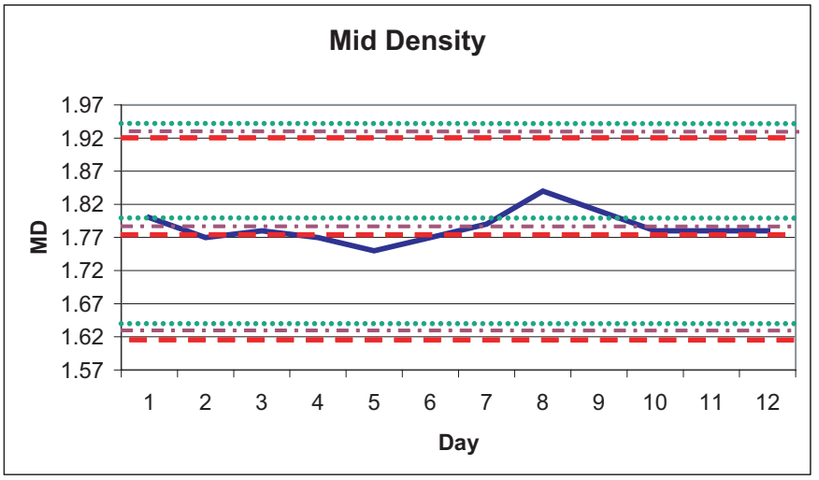
> The use of starter accelerates the seasoning process.

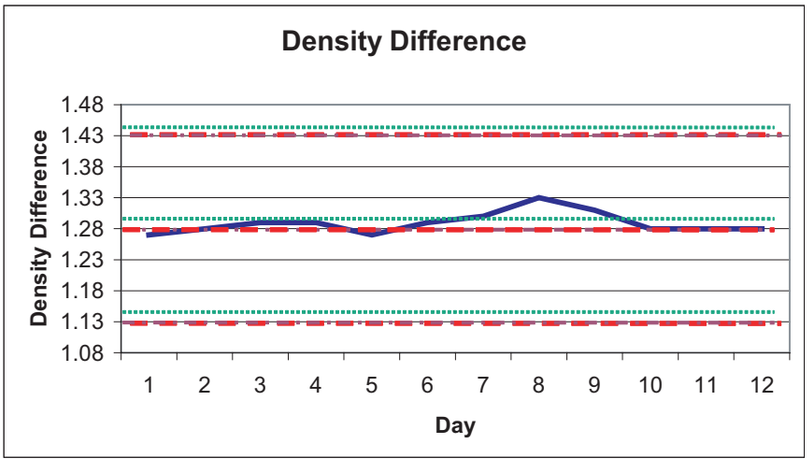
The baseline should be established on a seasoned processor. Establishing an aim prior to the point at which seasoning is reached will result in an aim that is higher or lower than the true operating point for the setup conditions. This will shorten one side of the operating range and could result in unnecessary service calls or QC concerns.

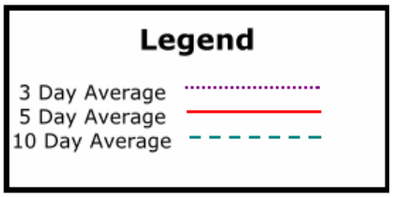
> Kodak recommends a minimum of five days (preferably including a weekend) to establish aims, but a longer period may ensure equilibrium. (This recommendation is based on amount of time to "turn-over" the solutions in the processor tank, and to balance out small variations due to set-up of processor and typical fluctuations in processing volume and use. Testing has indicated that 75% of the seasoning change occurs with one tank turn-over, 95% with two tank turn-overs and 99% with three.)

i) a temporary aim must be established (from several strips acquired at the time of fresh start). If the processor was set-up properly, the control variables should not exceed the typical control limits during the averaging period. If greater variability is noted while establishing aims, the cause must be investigated, corrected and a new average should be started.

ii) if the daily qc is consistently above or below the aim then the processor may have not reached equilibrium before the aim was established. Consider establishing new aims based on additional days following the initial set-up and document the rationale.







Note that for this particular environment (high volume deep tank processor), most of the seasoning was completed at the end of five days. There was still a small change in speed between 5 and 10 days of averaging.

Re-establishing Aims

The re-establishment of aims is recommended if there is any change in:

- film brand/type
- chemical brand/type
- replenishment rates
- specific gravity automixer settings
- film volume
- optical density
- sensitometer and densitometer
- processing cycle
- processor

If new aims are established it is important to validate that the clinical image quality is still acceptable!

NOTE: *Replacement of chemistry (same brand/type) as part of routine preventative maintenance should not necessitate establishment of new operating levels.*

Film Crossover Procedure

Perform a crossover procedure when a new box of QC film is opened to adjust the originally established parameters for speed, contrast, and base plus fog on the processor QC chart for the characteristics of the new emulsion. An adjustment is required because film used in medical imaging is produced in batches and there may be slight differences in the sensitometric characteristics from batch to batch. The conditions under which the film is stored (i.e., temperature, relative humidity, exposure to fumes from chemicals or to ionizing radiation, etc.) and the age of the film can also affect the sensitometric characteristics of film.

Performing a crossover procedure is necessary to maintain a controlled processing environment. Note the following important points:

1. The crossover should be performed on the same day rather than over five consecutive days as when the processor QC program was initially established.
2. Expose and process all of the films required for the crossover:
   - At the same time of day that processor QC is normally performed because slight sensitometric changes due to fluctuations in film feeding patterns throughout the day are common.
   - All at the same time, without interruptions.
   - With the same delay (e.g., a few seconds) between exposure and processing that is normally used.
   - Alternating the films from the existing QC box and from the new box. Expose and process the first film from the existing box, followed by the first film from the new box, the second film from the existing box, the second film from the new box, etc. This distributes any sensitometric changes due to seasoning equally among the 10 films. The films from the existing box and new box can easily be distinguished from each other before processing by marking one set of films with a lead pencil or by cutting a corner of one set of films, etc.
   - The computations and adjustments to the control chart may be delayed until a more convenient time later in the day, if preferred.
3. The chemicals in the processor should be seasoned when a crossover is performed on a single day. Generally, for this purpose, it is important to avoid performing a crossover immediately after a preventive maintenance procedure (PM). Monitor both the number of films remaining in the QC box and when the next processor PM will be performed so that the crossover can be performed before the PM occurs and with fully seasoned chemicals in the developer tank. A good rule of thumb is that a minimum of 10 to 15 films should remain in the existing box of QC film when beginning a crossover procedure. A piece of cardboard from the film box inserted between the last 15 films and the balance of the box makes a good divider and serves as a reminder that a crossover must be performed.
4. The processor should be in control (within the ± 0.10 control limits for speed and contrast) for crossovers performed all on a single day.It is extremely unlikely, however, that the speed and contrast of the processor will be at the operating level originally established. It will be necessary, therefore, to adjust the new operating levels (taken from the characteristics of the new film) by the difference between the originally established aims and the current box of film.
5. The developer in the processor must have reached its operating temperature before doing a crossover procedure.
6. The crossover procedure should be fully outlined in the policy and procedures manual, and all QC personnel should be trained.

Performing a Crossover

Follow these steps:

1. Alternately expose and immediately process five sensitometric strips each from the current and new boxes of film.
2. Determine the average of the steps previously chosen for processor quality control (i.e., step 11 for speed, steps 13 and 9 for contrast, and step 1 for base plus fog for the five films from the current box and for the five films from the new box).
3. Adjust the aim operating levels on the control chart for speed, contrast, and base plus fog by the difference in the average values between the current and new boxes of film, as shown in the following equations:

Step 1:				
New Box Average	–	Current Box Average	=	Difference
Step 2:				
Original Aim	+	Difference	=	New Operating Aim

4. Example #1: The original operating aim for speed is 1.20; the average for speed of the five films from the current QC box is 1.28; the average for speed of the five films from the new QC box is 1.32.

Step 1:	1.32	–	1.28	=	0.04
Step 2:	1.20	+	0.04	=	1.24

5. Example #2: The original operating aim for contrast is 1.80; the average for contrast of the five films from the current QC box is 1.75; the average for contrast of the five films from the new QC box is 1.70.

Step 1:	1.70	–	1.75	=	0.05
Step 2:	1.80	+	(–0.05)	=	1.75

To confirm that the correct adjustment has been made, check that the offset (or difference) between the new operating level and the point which represents the average of the five films from the new box of QC film is exactly the same as the offset (or difference) between the old operating level and the point which represents the average of the five films from the current box of QC film.

In Example #1 at left, the offset, or difference, between the current QC box average value (1.28) and the original operating aim (1.20) is 0.08, with the average being higher. The new QC box average value (1.32) is also 0.08 higher than the new operating aim (1.24).

In Example #2 at left, the offset, or difference, between the current QC box average value (1.75) and the original operating aim (1.80) is 0.05, with the average being lower. The new QC box average value (1.70) is also 0.05 lower than the new operating aim (1.75).

Record the complete emulsion number of the new box of film on the control chart.

Make a notation in the "remarks" section recording the date and the fact that a crossover was performed.

Chapter 5: Troubleshooting

Troubleshooting:

It cannot be overemphasized that establishing and maintaining high quality images is critical to a successful mammography imaging program. Earlier sections of this guide have discussed Kodak 's recommended setup of the MIN-R EV film system to achieve such high quality images. Once this has been established, it is important to monitor quality on an on-going basis, and react quickly to correct any problems/deviations once discovered. It is impossible to eliminate the potential for problems to occur or to expect that image quality will never deteriorate and that test results will not deviate from the benchmark. Through appropriate monitoring and some basic problem solving considerations, issues can be quickly resolved, preferably before any impact on the clinical images is noted.

In this chapter, basic quality control tests and/or procedures are discussed with respect to detecting and correcting potential problems in mammographic imaging. The discussion below is not a comprehensive discussion of quality control (QC), nor of the tests that should be performed but a guide for troubleshooting and assisting in maintaining image quality. Many breast screening programs or countries have defined specific quality guidelines to be followed, for example, in the United States refer to the Mammography Quality Standard Act or the Mammography Quality Control Guidelines of the ACR. These programs define specific tests to be followed, and the frequency with which they should be performed. It is important to follow the guidelines/regulations required in your area.

Mammographic imaging is a multi-stage operation; the combination of these stages may be referred to as the imaging chain. Please refer to figure xx on page xx (note to TKM-this is dependent upon formatting) for the complete imaging chain. In a very simplified view there are three major elements that define the imaging chain: exposing, processing and the positioning of the patient. Associated with these three imaging steps are three important quality tests. The first is **processor QC** which is performed to monitor the film-processing environment. The second is **phantom QC** which is an imaging test to monitor the combination of the exposing and processing environment (since all films must be processed, it is impossible when using film in the QC test to separate the clinical from the processing). Most importantly is the final step, which is monitoring the clinical images for diagnostic quality, referred to as **clinical image QC**. Clinical images encompass the entire imaging change including the patient, technologist and radiologist interpreting the displayed image. This is the most critical evaluation. Many QC programs have not defined an easy way to monitor this, so the clinical image is often overlooked or neglected when monitoring the on-going quality of the imaging system. All facilities should establish a communication between the radiologists, technologists and medical physicists to include the clinical image as part of the routine evaluation of image quality, and further to include an assessment of the clinical image whenever other quality control tests, i.e., processor or phantom is in question.

> No change in QC testing or corrective action should be made without first evaluating the effect on the clinical image.

The imaging chain actually involves more steps, and there are many additional factors to consider than these three simple QC concepts. These three tests can be effectively used to narrow down which portion of the imaging system to investigate when quality concerns arise.

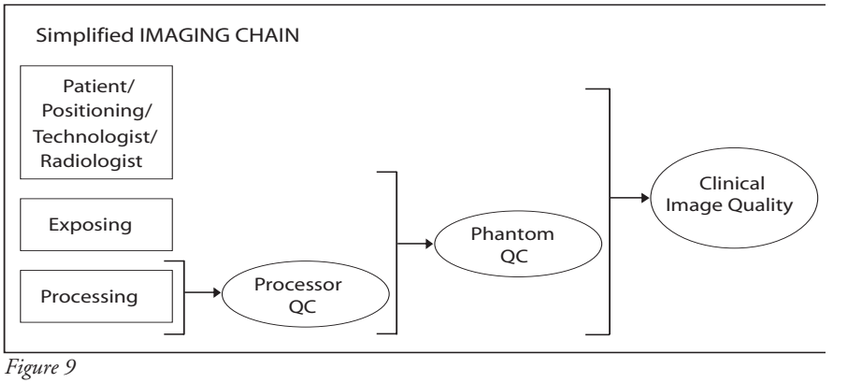


Figure 9

Once the problem can be localized, a more detailed breakdown of the imaging chain can be used to investigate the problem. Additional factors to consider are shown in Figure 10.

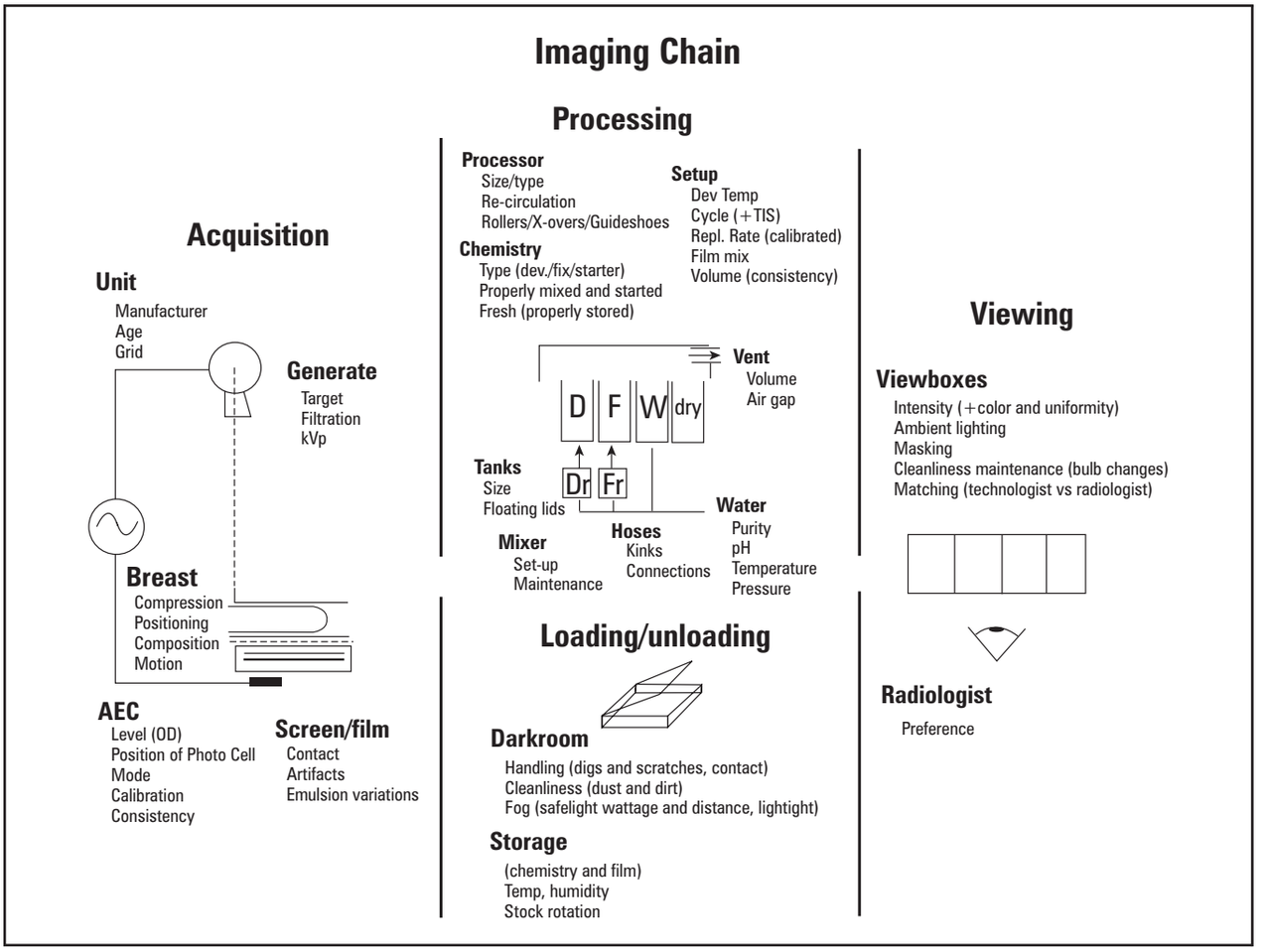


Figure 10 Proper set up, benchmarking and a thorough quality assurance program will help maintain consistent image quality from one year to the next.

Prior to troubleshooting and/or changing anything in the Imaging Chain, it is important to determine if the concern is with the QC charts, phantom charts or clinical image or any combination.

When troubleshooting, it is important to have a known optimized point of comparison. For this reason it is helpful to retain the initial QC film, phantom and log of initial optimized patient images as a reference or benchmark when first converting to MIN-R EV film.

Benchmarking

Most QC programs specify a period of time for which to keep QC records (typically greater than 1 year) including the routine test for **processor QC** and **phantom QC**. It is helpful to refer to these records and earlier images when problems arise.

Since a quality control test specifically for **clinical image quality** has not been defined, Kodak also recommends that facilities keep a log of some initial patient images at the time of successful conversion to MIN-R EV film, or when a major change to the system was made as well as the processor, QC film and a phantom image to serve as a benchmark. Please refer to Chapter 3.

When a concern arises over clinical image quality, these images can be retrieved and compared to the present image quality.

BEST PRACTICE: Always repeat a quality control test that falls outside operating limits to verify that a true variation is being detected before corrective action is taken.

Processing

Processor QC

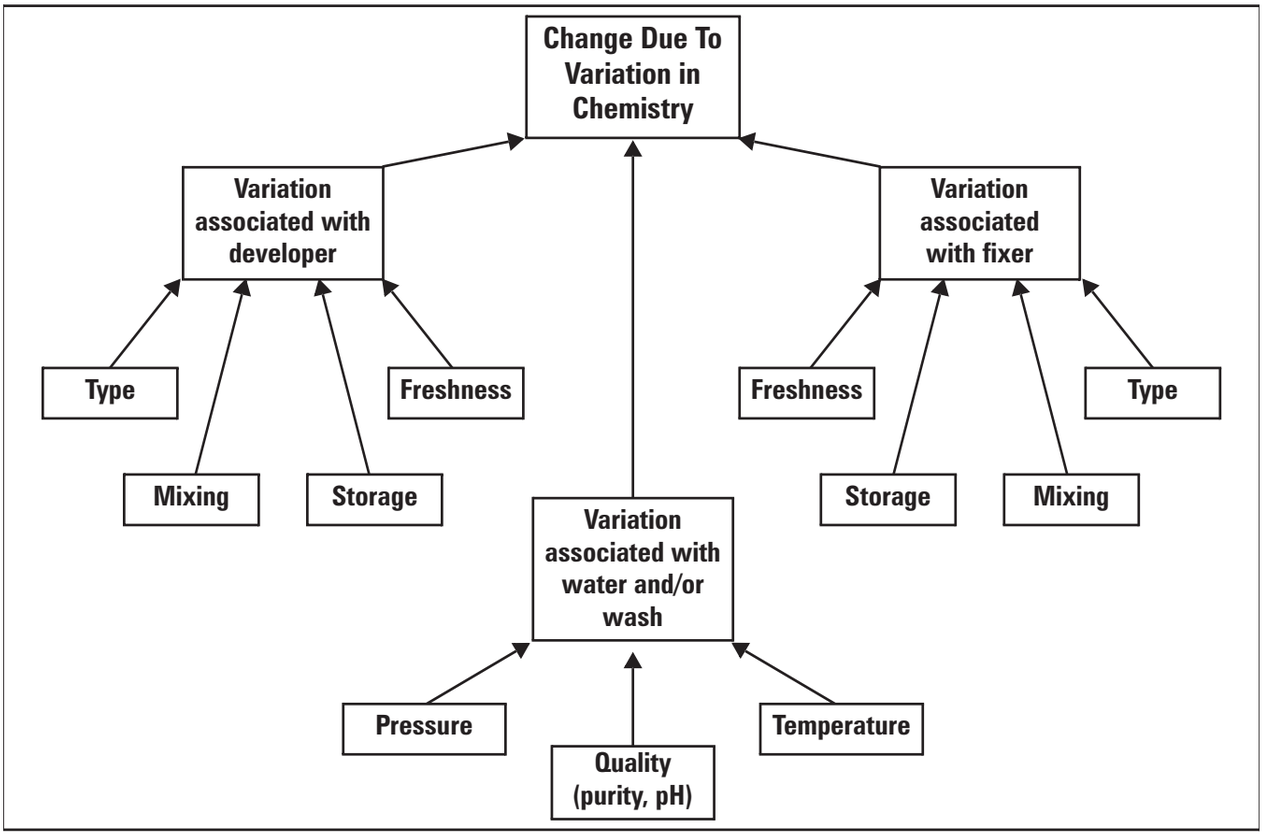
A processing environment that is properly setup and maintained will produce very consistent image quality. As part of maintaining the processing environment, most QC programs should have a test for monitoring the properties of processed film. (Please refer to Chapter 4.)

The daily processor QC must be performed prior to any clinical imaging.

- Several factors are important in understanding processor QC.

1. Processor QC is only as good as the initial reference so it is important that the processor is set up correctly.
2. The QC film should be processed at the same time each day, after the processor has been started and has had time to warm-up prior to clinical imaging or batch processing.
3. A change in processor QC is not necessarily a change in clinical image quality. Concern for changes in processor QC should be tempered by the quality of the clinical image.
4. If processor QC shows a trend (please refer to Troubleshooting Trends in QC Charts) or falls outside of control limits, then all the elements of the film and processing environment should be considered (see detailed imaging chain).
5. Processor QC monitors only several easily measured characteristics of the film processing environment. Some processing related factors such as image tone and dye stain may not be detected by monitoring processor QC only.
6. If the processor QC is out limits or is showing a trend:
   - Redo the test
   - Verify that the processor is set up correctly
   - Determine if the workload has changed
     - Replenishment rates may need to be adjusted
   - Review Chapter Two for chemistry affects

Image Quality/Processor QC variation caused by chemistry



Troubleshooting Trends in QC Charts

What is a trend?

A trend is any deviation in the same direction from the established aim for longer than three days.

When Mid Density (MD) or Speed Index (SI), Density Difference (DD) or Contrast Index (CI), and Base + Fog (B + F) differ greatly from expected values and/or indicate an out-of-control processing environment (e.g., reaching or exceeding ±0.15 of the operating levels for MD and DD), always generate another sensitometric strip, making sure that:

- The emulsion side of the film was toward the light source of the sensitometer.
- The temperature of the developer solution in the processor has stabilized before exposing and processing the sensitometric strip.
- The settings on the sensitometer were properly set, i.e., single-sided exposure for single emulsion films, double-sided for double-sided films, appropriate spectral sensitivity (green or blue), recommended DIP Switches (if the sensitometer is exposure adjustable), etc.
- The film used was taken from the box set aside for processor quality control.
- The delay between exposing and processing the film is as normally occurs from day to day. (Note that immediate processing after exposure of the sensitometric strip by the sensitometer is recommended.)
- The same densitometer was used to measure MD, DD, and B + F values.
- The calibration of the densitometer is correct.
- If an automatic scanning densitometer is used, the correct channel was used and the programming has not been changed.
- *It may be recommended to expose another phantom image at normal settings and determine if the same trend visible on the QC chart is also visible on the phantom's background density and density difference.*

Please Note:

- If the numbers are out of limits, adding additional starter or partially filling the developer tank with fresh developer is not recommended.
- Retaining the developer solution after a processor maintenance is not recommended.

Compare MD, DD, and B + F results from the processing control chart to the information below to determine possible causes and corrective actions.

Trends in Graph	Possible Causes	Corrective Actions
MD: ↓ DD: ↓ B+F: →	Severe under-replenishment	• Check developer replenishment rate • Check that rate is set as recommended in Service Bulletin No. 30 • Check for kinked or air-locked developer replenishment line • Check for improperly mixed (over diluted) developer replenisher • Check amount of water added • Check chemical usage • Check for change in film volume since rate was set and adjust accordingly (raise) • Communicate changes in film volume to processor service firm
MD: ↓ DD: ↓ B+F: ↑ or →	Severe Contamination of developer with fixer	• Call service to clean the processor • Drain developer tank • Thoroughly flush tank and developer rack with water • Change the developer filter • Use splash guards • Remove and insert the fixer rack carefully • Process films with edges in contact with film feed tray guides to avoid film jam
MD: ↓ DD: ↓ B+F: →	Severe oxidation of developer	• Always use a floating lid on top of the developer replenisher inside the holding tank • Check the developer replenishment rate • Call service to check the processor
	Exhausted developer	• Check developer replenishment rate • Check that rate set as recommended in Service Bulletin No. 30 • Check chemical usage • Check for change in film volume since rate was set and adjust accordingly • Communicate changes in film volume to processor service firm • Check processor ventilation
MD: ↓ DD: ↓ D-Max: ↓ B+F: ↑	Expired film	• Check film expiration date • Manage film inventory using first-in, first-out method
	Film stored above the recommended temperature and relative humidity	• Store unprocessed/unexposed film and processed radiographs between 50 to 70°F (10 to 21°C) and 30 to 50% relative humidity
MD: ↑ DD: ↓ B+F: ↑ or →	Over-replenishment	• Check Service Bulletin No. 30 for recommended rates and adjust accordingly.
	No starter added to fresh developer in processor developer tank	• Check Service Bulletin No. 30 for the amount recommended for chemistry, film and processor in use • Add the correct amount of KODAK RP X-OMAT Developer Starter
	Insufficient amount of starter added to fresh developer	• Add the correct amount of KODAK RP X-OMAT Developer Starter
	Safelight Fog	• Perform darkroom fog test.

Trends in Graph	Possible Causes	Corrective Actions
MD: ↑ DD: ↑ D-Max: ↑ B+F: ↑ or →	Slight contamination of developer with fixer	• Call service to clean the processor • Drain developer tank • Thoroughly flush tank and developer rack with water • Change the developer filter • Use splash guards • Remove and insert the fixer rack carefully • Process film with edges in contact with film feed tray guides to avoid film jams
MD: ↑ DD: ↓ B+F: ↑ or →	Developer temperature higher than recommended (within 5°F [3°C])	• Measure developer temperature using accurate or calibrated thermometer • Verify developer temperature set as recommended in Service Bulletin No. 30 for model of processor • Lower thermostat to correct temperature • Check thermostat to correct temperature • Check water flow and temperature
	Water temperature higher than recommended (if developer temperature set above set point)	• Check temperature of incoming water • Verify water temperature set as recommended in Service Bulletin No. 30 for model of processor • Install mixing valve to regulate water temperature
	Developer time longer than recommended	• Check immersion time using time-in-solution test tool
MD: ↓ DD: → or ↓ B+F: →	Developer temperature lower than recommended (within 5°F [3°C])	• Measure the developer temperature using accurate or calibrated thermometer • Verify developer temperature set as recommended in Service Bulletin No. 30 for model of processor • Raise thermostat to correct temperature • Check thermostat and recirculation pump for malfunction • Check water and temperature
	Water temperature lower than recommended (if developer temperature below set point)	• Check temperature of incoming water • Verify water temperature set as recommended in Service Bulletin No. 30 for model of processor • Install mixing valve to regulate water temperature
	Developing time shorter than recommended	• Check immersion time using time-in-solution test tool
MD: ↓ DD: ↑ B+F: → D-Max: ↓	Too much starter added to fresh developer (>50 percent)	• Check Service Bulletin No. 30 for the amount recommended for the model of processor in use. • Add the correct amount of KODAK RP X-OMAT Developer Starter

The following are not normally monitored but can affect clinical images:

- D-Max (the area of darkest density on the clinical image and H&D curve)
- Shoulder of the H&D Curve (breast periphery on the clinical image)
- Dye stain
- Tone

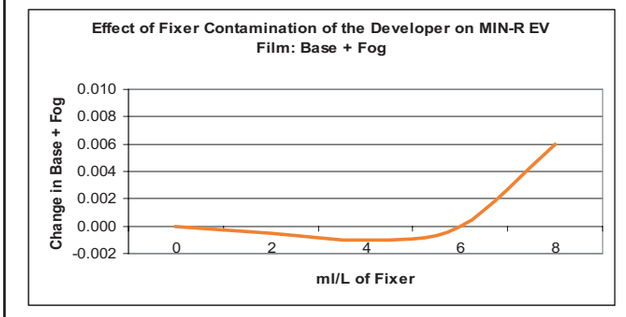
- Although often overlooked in many QC programs, when changes to the processing or exposing environment are made, the clinical image quality should be validated before the new reference is established.

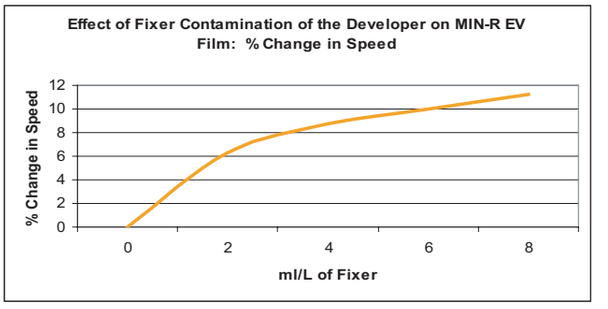
Other Processor/Film Related Issues

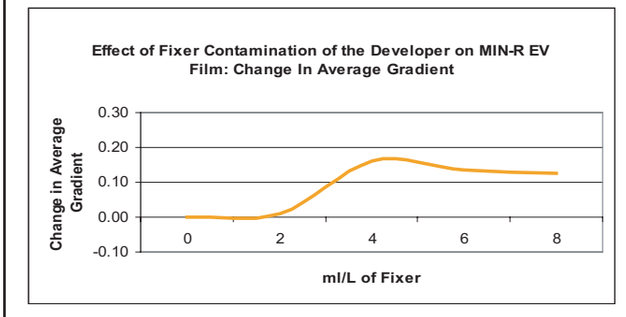
Fixer Contamination of the Developer

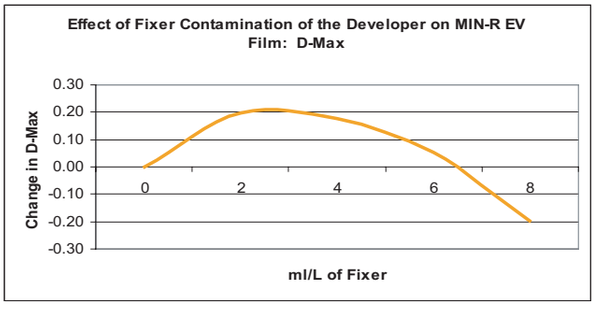
A common cause of changes in QC/and or image quality is fixer contamination of the developer. This can be caused due to a film jam, improper processor ventilation, or an unlevel processor.

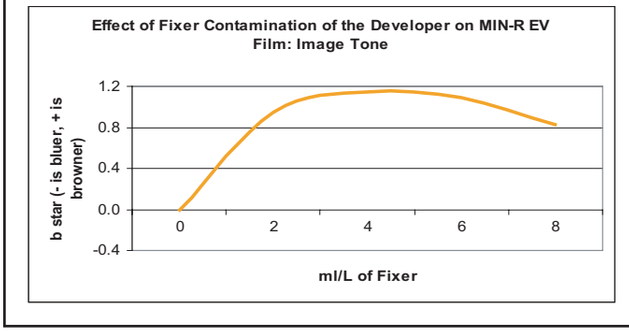
Varying results may occur depending on the film and fixer type and the level of contamination. Some mammography films initially react by exhibiting an increase in contrast and D-Max with low level contamination. It is a common misconception that fixer contamination is indicated by an increase in fog in all films. The reaction of MIN-R EV film is characterized by an increase in speed and warmer image tone as illustrated in the charts below.











Processing Artifacts

Introduction:

Artifacts are defects on processed film. Artifacts can happen pre- and post-exposure, during processing and after processing.

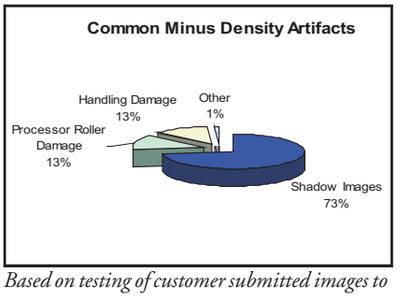
Minus Density Artifacts

These artifacts appear white or lighter than the surrounding background. They are of particular concern in mammographic imaging due to the use of single screen.

Causes:

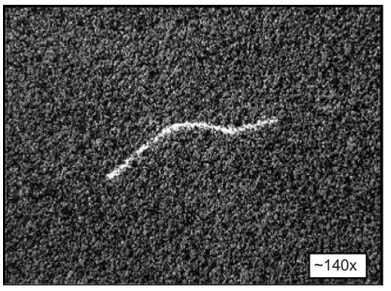
- Shadow Images
- Processor Digs
- Handling

The most frequently occurring minus-density artifact, however, is termed shadow images.

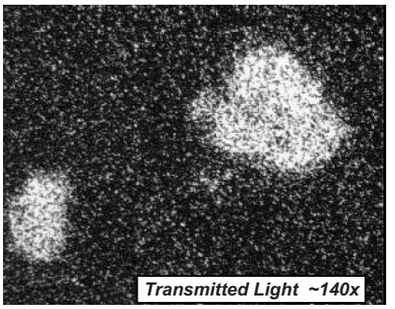


Based on testing of customer submitted images to the Kodak Colorado Microanalysis Lab 2003

Shadow images are caused by dirt and dust superimposed inside the cassette between the intensifying screen and film emulsion. Shadow images appear as small, random, minus-density spots on the film, and are frequently confused with pick-off or processor digs. It is estimated that shadow images may account for the majority of minus-density artifacts seen on mammographic images.



A shadow image caused by a fiber



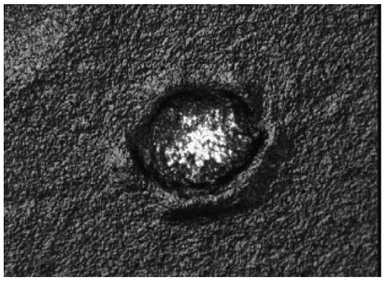
Shadow image caused by dust or dirt.

Controlling shadow images is dependent upon:

- Properly cleaning the surface of intensifying screens and cassette interiors as recommended
- Periodically cleaning the interiors of film magazines and roomlight film handling devices, such as the KODAK X-OMAT Miniloader 2000 and
- Proper darkroom hygiene

The high contrast of KODAK MIN-R EV Film, however, may increase the visualization of minus-density artifacts, necessitating even more care in maintaining a clean darkroom environment and clean intensifying screens and cassettes. For cleaning instructions, please refer to the Darkroom and Screen sections of this guide.

Processor Digs



A typical processor dig, magnified 140x.

- When the emulsion is in the processor developer and fixer solutions, it is swollen and very soft.
- If this wet, swollen emulsion encounters a roller on which a relatively hard particle is adhered, it is very easily displaced.

Appearance:

Processor digs appear as very small minus-density spots on the film where the emulsion has been removed down to the film base. Often the piece of the emulsion that is removed may be deposited on the film near the trailing edge of the minus-density mark or may be deposited randomly on the film. Processor digs are most apparent on single screen images. Processor digs are most visible in transmitted light. Unlike shadow images, processor digs can also be seen in reflected light.

Causes:

- Rough/dirty rollers
- Inactive processing chemicals
- Varying transport speed

Remedies:

- Do the periodic maintenance procedures as outlined in the Service Manual.
- Mix new processing solutions.
- Check the surface finish of the knurled rollers for excessively sharp or rough areas. If necessary, install new rollers.
- Check the turnaround and cluster rollers.
- Check the replenishment rates for the developer and fixer solutions.

Cleanup Film

KODAK Roller Transport Cleanup Film 4955 (CAT No. 122 4310) is a specialized film designed to be used in conjunction with the processing environment. Each 14 x 17 in. (35 x 43 cm) sheet of film features a non-light-sensitive coating on both sides of the film base.

Cleanup film picks up lint, dirt, and other deposits and helps carry them out of the processor. For best results, one or two sheets should be processed. Cleanup film is particularly useful to control a processing artifact called delay streaks. Cleanup film may be used in all processors, except those with area replenishment and multiloaders and miniloaders that cannot sense this clear-based film.

Fogged or expired single- or double-emulsion film that has not previously been processed may also be used as cleanup film. Note that mixing films from different manufacturers in the same environment should be avoided, as undesired sensitometric changes may occur.

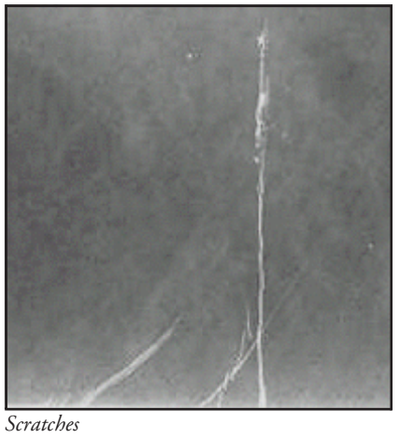
Any film used as cleanup film should be discarded after one use to avoid contaminating the developer solution with fixer and redepositing lint or dirt back onto the rollers in the processor.

Contact your local Kodak representative for additional information about KODAK Roller Transport Cleanup Film 4955.

Handling Artifacts

Handling Artifacts are generally caused by pressure on the film emulsion and may be either plus-density or minus-density marks in appearance.

Minus Density Fingerprints



Scratches

For cubic grain films such as MIN-R EV, pre and post exposure artifacts are minus density. Pressure or mishandling before exposure can occur before the film box is opened, after an opened box has been placed into the film bin, or as film is removed from the box and placed into the cassette. Pressure or mishandling after exposure can occur as exposed film is removed from the cassette and placed on the film feed tray for processing.

Grease Pencil Test to Determine Source of Minus-Density Artifacts

Tools required:

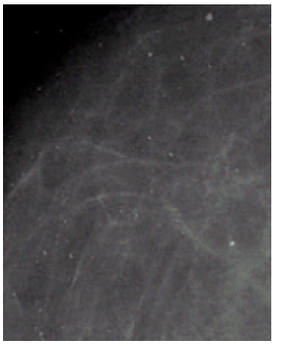
- Film with minus-density artifacts
- Red or yellow grease pencil
- Lint-free wipe (used for screen cleaning)

Procedure:

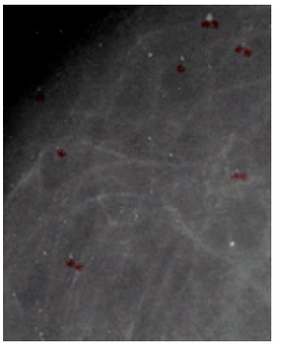
1. On the emulsion side of the film, use the grease pencil to lightly color in all the minus-density spots that are of concern. Too much pressure will negate the test, as the grease mark will not be able to be wiped off.
2. Take the wipe and gently clean away the grease pencil marks from all the spots colored.

Analysis:

1. The minus-density spots that are cleaned of red grease pencil marks are shadow images caused by dust/dirt.
2. The minus-density spots that DO NOT clean and remain red are caused by processor digs.

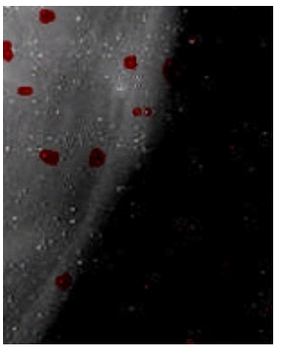


Exhibits shadow images caused by dust and dirt.



The grease pencil marks are cleaned off around the minus density artifacts.

Exhibits processor digs

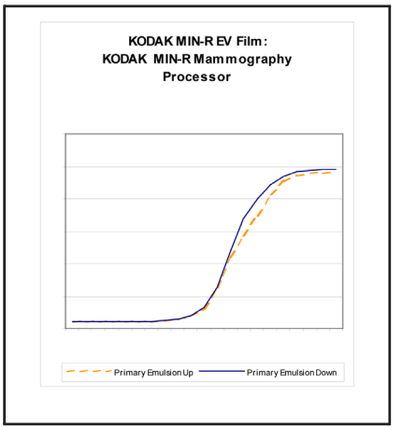


The grease pencil marks remain red.

Processing Nonuniformity

Processing nonuniformity, characterized by uneven optical densities on radiographs, may occur when KODAK MIN-R EV Film is processed emulsion side up in the following processors: KODAK X-OMAT M35A-M, M35M and MIN-R Mammography Processors. The nonuniformity occurs due to the accumulation of processing by-products adjacent to the film emulsion inside the developer rack. Besides nonuniformity, the characteristic curve plotted from the information from a sensitometric strip may also reflect nonuniformity at approximately 2.20 to 3.00 optical densities.

Due to non-uniformity issues processing KODAK MIN-R EV Film emulsion side down is recommended in the processors noted above. This allows developer solution to reach the primary emulsion more efficiently, reducing the occurrence of nonuniform development.



Additionally, it is necessary to install smooth guide shoes in the developer rack to reduce guide shoe marks accentuated by processing film with the emulsion side down. Refer to *Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film*, publication no. M3-110 for information on guideshoe kits for specific processors. (This publication is

also located in the Appendix). Contact your local Kodak representative, visit Kodak's Health Imaging Internet site (www.kodak.com/go/mammo), or contact Health Imaging Technical Support at 1-800-328-2910 (1-972-805-1500).

Phantom QC

Test objects, or phantoms, are used in the evaluation of mammographic imaging systems to monitor system performance. Phantom QC uses a standard test object to produce images daily/weekly/or as mandated to assess the exposing and processing characteristics of the imaging system.

> Mammography reflects the imaging of various tissue types and thicknesses. It is possible that a subtle change in the exposure parameters or equipment may impact the clinical image and may not be detected on the phantom QC.
>
> Phantoms are useful for assessing:
>
> - Optical density consistency
> - Contrast (density difference)
> - Image quality of a particular breast type and thickness.

Daily phantoms are recommended. Phantoms monitor optical density and/or contrast and can provide objective image quality assessments (score).

For consistent results, one cassette/screen should be identified and used to create the phantom image. One technologist should score the phantom using the same viewbox. If a different technologist scores or if a different viewbox is used this should be noted on the form.

- Phantom technique must reflect clinical technique used
  - AEC mode for breast type and thickness similar to phantom thickness and composition
    - Example: RMI 156 4.5 cm 50/50 breast or as mandated (block phantom with a step wedge may be utilized).
  - Consultation with lead interpretative radiologist at time of conversion and quarterly will ensure phantom score reflects clinical practice.
  - Test procedure must be consistent for:
    - Position on bucky/grid cassette holder (Image Receptor)
    - Position of AEC detector
    - Compression thickness and force
    - Technique selection, i.e., AEC mode
    - Viewbox used
    - Technologist scoring.
- Phantom QC change when the processor is in control
  - Redo test
  - Check procedure
  - Emulsion change
  - kVp, mAs, anode, filter same for AEC mode

    Prior to any test procedure change, ensure that the clinical image is also affected.

Troubleshooting the Phantom

Optical Density Changes:

When the phantom is too dark or too light, consider/ensure the following:

- Redo the test
- Is the processor is in control?
- Was the same cassette used?
- Refer to the benchmark phantom to determine the reference optical density.
- Has the clinical image changed?
- Have the technical factors changed?
- Ensure that the phantom position and Automatic Exposure Position (AEC) are the same as in the benchmark test.
- Perform a split phantom test to determine if clinical film emulsions differ.

If the split phantom test indicates that the difference in optical density between emulsions is greater than 0.30, the film manufacturer should be consulted. If the processor is not in control, corrective action must be taken. The phantom test must be repeated once the processor is in control. Please refer to page 90 for the split phantom procedure.

- Do not make adjustments until it is determined what the impact on the clinical image will be.

Density Difference (Contrast) Changes:

When the density difference or contrast of the phantom changes, consider the following:

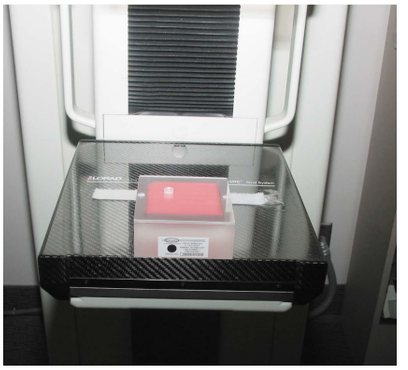
- Redo the test
- Is the processor is in control?
- Was the same cassette used?
- Ensure that the position of the phantom, compression and position of the AEC detector is the same as in the benchmark phantom.
- Have the exposure factors changed?
- Higher kVp, use of Rhodium filter and/or Rhodium and Tungsten anodes can reduce the density difference.

Changes in the Phantom Score

When there are changes in the phantom score, consider the following:

- Redo the test
- Is the processor in control?
- Technique change (i.e., kVp, mAs)
- Compare to benchmark phantom for optical density and density difference.
- Ensure that the position of the phantom, compression and position of the AEC detector are the same.
- Record reasons for increase or decrease in score.

BEST PRACTICE: If the score increases, investigate and implement the change into clinical practice.



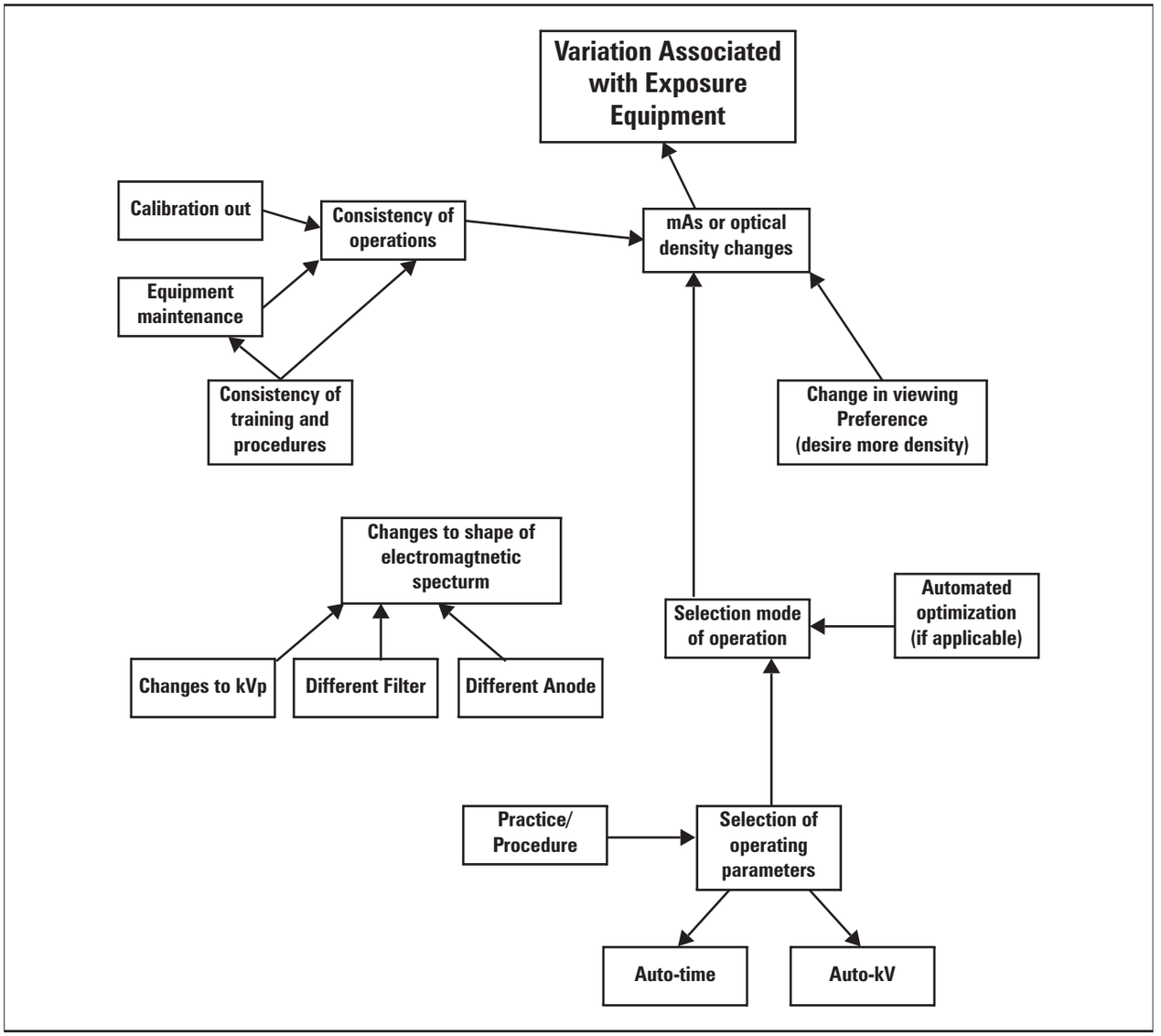
Clinical Image Quality

The clinical image involves the entire imaging chain so any problem in the system has the potential to affect the clinical image. Monitoring clinical image quality, therefore, is critical to ensuring high quality images. Since all aspects of the imaging chain are involved in the creation of the image, it can be difficult to determine the impact changes in the imaging chain can have without an organized approach to troubleshooting. The clinical image must be combined with the analysis from the processor and phantom QC as these are the most likely sources of routine changes. When clinical images vary from the previous without a change in the phantom or processor QC consider:

1. A change in technical factors (e.g., change in optical density, change in kVp). A patient identification (id) camera which includes the technical factors used (exposure mode, time or mAs, kVp, sensor/detector position, breast thickness, compression force and anode filter combination and other factors) is useful to compare to the technical factors used for a previous clinical image.
2. Viewing condition changes (intensity and uniformity of the viewbox) – clean or replace dirty or damaged diffusers. Verify that the use of masking and control of ambient light has not changed.
3. A drift in QC parameters – i.e., small changes over time which may have resulted in an adjustment of the QC parameters without verifying the impact on clinical image quality. Previous QC records from the successful conversion to MIN-R EV will be helpful in determining if there has been a change from the baseline QC. Please refer to page 76 for benchmarking best practices.
4. Radiologist preference change: Images that were identified at the time of conversion, as representative of the preferred image quality can be helpful. Confirm the preferred technique by performing the following as outlined in Chapter 3:
   - kVp series
   - Optical density series

BEST PRACTICE: Periodically perform these evaluations to ensure that preferences are not changing over time.

Why My Films Don't Look the Same



Troubleshooting the Clinical Image

First, review the present technique factors as they compare to techniques used previously. Facilities techniques may "drift" from previously established parameters.

This may be associated with

- exposure control adjustments
- drifts in processing
- changes in viewing conditions
- changes in preferences.

When comparing exams of the same patient from year to year, to determine the cause of variability.

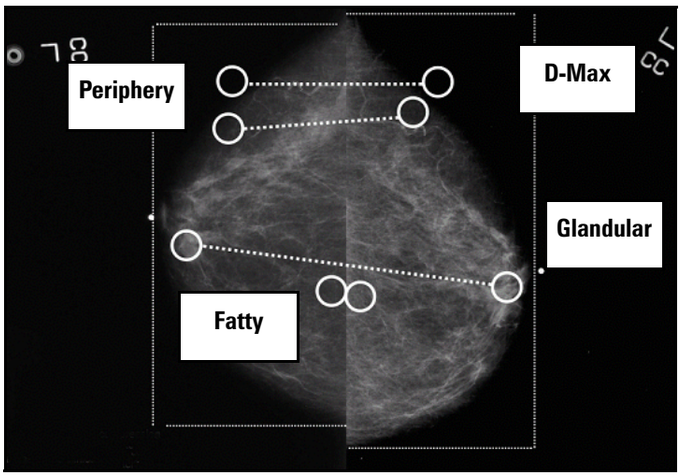
- Is it positioning?
- Is it technique?
- Is it compression?
- Is it contrast?
- Is it too dark?
- Is it too light?

BEST PRACTICE: Any change should be investigated, corrected, understood and communicated to all staff.

- Quarterly meetings to evaluate clinical image quality, determine what has changed and take corrective action:
- Document any change and have all technologists sign acknowledgement if technical factors have changed.

Other Tips / Helpful Reference

To determine the causes of image quality concerns, refer to your benchmark images (QC, phantom and clinical) from time of conversion.



Note differences in compression and density in matched images

1. Compare kVp, compression, positioning, anode and filter, screens and x-ray equipment versus your previous.
   a. Measure the optical density in the glandular tissue, fatty areas, pectoralis muscle and the D-Max (area of darkest density) and compare to your previous clinical image.
   b. Determine if there is any tone difference between present and previous image.

Tips for Troubleshooting and Improvement

When using automatic exposure control, differences in compression and positioning can result in different technical factors that will affect contrast.

Poor compression may cause motion blur.

NOTE: *It is very important to determine whether the loss of image quality is due to contrast or optical density changes.*

Contrast

- **Increased contrast**
  - Images appear black/white
  - Fatty tissue overexposed
  - Glandular tissue may be under exposed
  - Loss of skinline and breast periphery.

  Check

  - Processor changes (see QC trends)
  - kVp too low
  - Anode filter Mo/Mo when Mo/Rh, Rh/Rh or Wo/Rh should be selected for breast type imaged.

NOTE: *the high film contrast of MIN-R EV film may result in high radiographic contrast. Consider adjusting technique factors. Use of higher kVp or Rhodium can lower dose to the patient and still produce excellent image quality.*

Subject Contrast	+	Film Contrast	=	Too High Radiographic Contrast
kVp low Mo/Mo		MIN-R EV high or Processing Changes		

- Decreased Contrast
  - Images appear flat, grey
  - Washed out, lack crispness and sparkle

  Check
  - Processor changes (please refer to QC Trends)
  - kVp too high

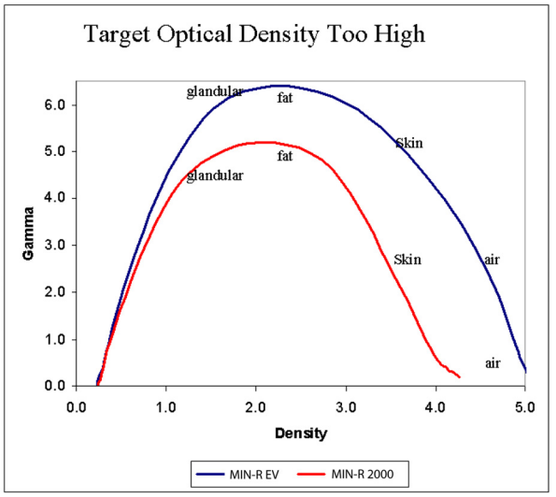
Anode Filter	
Rh/Rh Mo/Rh Wo/Rh	When Mo/Mo should be selected for breast type imaged

  - Optical density too low

Subject Contrast	+	Film Contrast	=	Too Low Radiographic Contrast
High kVp Rh/Wo Anode Rh Filter		Min-R EV and/or Processing Changes		

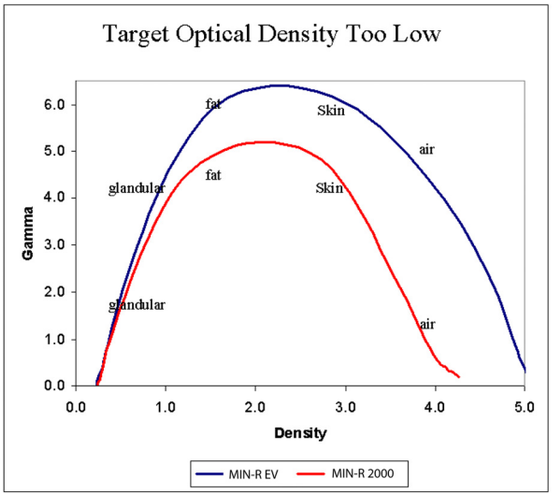
Optical Density

- Overexposed (too dark)
  - Breast periphery and fatty tissue may appear lower in contrast



If the optical density is set too high, glandular tissue may be penetrated, but other areasof the breast will be too dark. Fatty tissue and breast periphery may appear low in contrast.

- Under exposed (too light)
  - Glandular tissue will not be penetrated – abnormalities may be missed.



If the optical density is too low, portions of the breast image will be under exposed and may exhibit low contrast. The breast parenchyma may not be adequately penetrated.

Check:

- Processing changes?
  - See processing section, page 14
- Technical Factors changed
  - Follow established techniques
- AEC detector position
  - Place the detector under the glandular tissue or the area of interest
- Correct screens used-are different speeds of screens used in the department?
- Emulsion changes
  - Perform split phantom test, see page 90
- Viewing Conditions

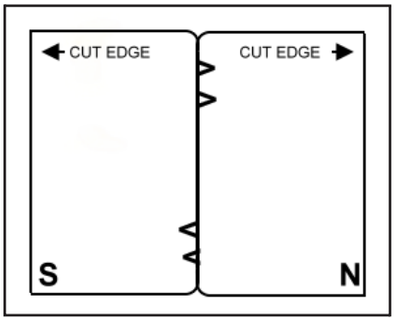
Split Phantom Test

A split phantom test should be performed to radiographically determine relative speed differences between two different emulsions of film, one of which is suspected of being much faster or slower than the film in current use for either clinical films or for processor quality control. Speed comparisons made using a sensitometer may not accurately reflect the differences in speed between two films exposed by light from an intensifying screen as is done clinically.

The procedure is as follows:

Tools:

- A phantom used for mammography quality control testing.
- The 18 x 24 cm mammography cassette normally used for the phantom test.
- A piece of cardboard from the film box cut in half to use as a guide.
- A pair of scissors.
- A lead pencil.



The mammography x-ray unit and the processor will also be used for this test.

Note that roomlight film-handling systems may not be able to remove the two pieces of film from the cassette or the films may not transport properly. If the roomlight film-handling equipment is installed through the darkroom wall and has a back door, the two films may be processed using that route. Place the film in larger cassettes. Alternatively, the two films may be processed in the processor used as backup for the mammography processor, or in any other processor available elsewhere in the facility.

1. In the darkroom, in total darkness to reduce any additional density added to the films due to long safelight exposure, cut a sheet of film from the current box in half by using the cardboard as a guide. (This can be done by lining up the 18 cm edges of the cardboard and film, with the film closest to the countertop and the cardboard half on top. Use care in cutting the film in the dark.)
2. Place the film emulsion side up in the cover of the opened cassette with the film on the right side and the cut edge toward the right edge of the cassette; use a lead pencil to mark the corner N for normal.
3. Cut a sheet of film from the suspect box in half by using the cardboard as a guide.
4. Place the film emulsion side up in the cover of the opened cassette with the film on the left side and the cut edge toward the left edge of the cassette; use the lead pencil to mark the corner S for suspect.
5. Make sure the film edges in the center of the cassette are directly adjacent to one another and not overlapping before closing the cassette.
6. Place the cassette with the two film halves in the bucky (image receptor) of the mammography x-ray unit.
7. Place the phantom on top of the grid in the standard location used for mammography quality control testing.
8. Position the photocell beneath the center of the phantom (standard location), assuming the phantom exposure is always made using the phototimer.
9. Select the same technique factors usually employed when imaging the phantom (same kVp, etc.).
10. Make the exposure and process the two film halves immediately in the same manner (e.g., emulsion side up and on the right side of the processor).
    NOTE: *Daylight handling system should not be used to unload the cassette. Place in larger cassettes. Film halves should be manually fed through the processor.*
11. Use a densitometer to take two optical density readings in the center of the phantom, just to the right and left of the cut edges (one on the normal and one on the suspect film).
12. Calculate the density difference by subtracting the optical density value of the suspect film from the optical density value of the normal film.

If the density difference is a negative value and the suspect film is darker than the clinical film, the suspect film is faster. If the density difference is a positive value and the suspect film is lighter than the clinical film, the suspect film is slower.

According to the American College of Radiology (ACR) in *Mammography Quality Control Manual (1999)*:

"If a change in phantom image background optical density or DD reaches or exceeds the recommended performance criteria, then it will be necessary to determine the source, or sources, of this change, e.g., the processor, film emulsion batch, X-ray generator, etc., and the problem should be corrected immediately. Document corrective action for future reference and compliance with MQSA regulations. If the change in film optical density is confirmed to be due to a change in the film emulsion batch, and if the magnitude of the change is within the expected batch-to-batch variation for that film type, then an adjustment of the density control setting to bring the phantom background optical density back into control is an appropriate corrective action." (page 186).

The 1995 ACR publication, *Recommended Specifications for New Mammography Equipment*, suggests that:

- "A density difference of 0.30 between any two films of the same type from the same manufacturer, exposed and processed together, is a reasonable maximum to be expected from manufacturing variability for films of roughly the same age and storage conditions.
- If the difference between the two film densities exceeds 0.30 at a density of approximately 1.25 (as specified by the test), then the film supplier should be contacted to determine the source of the problem."

Note that a difference of 0.30 at a density of approximately 1.25 may translate into a bigger difference for clinical films exposed at a greater optical density. For example, high-contrast mammography films, such as KODAK MIN-R EV Film, are frequently exposed at an optical density between 1.60 to 1.90 in order to maximize contrast. The density difference at this optical density level may be greater due to the increased contrast.

Image Tone

- Optical Density will play a major role in the appearance of tone (higher density=less blue, warmer or browner).
- Tone can be influenced by the spectrum and intensity of light from the viewbox. Viewbox factors include:
  - the spectrum from the fluorescent lamps,
  - the spectral transmission of the diffuser and
  - the reflective interior of the viewbox
- To compare tone between images it is essential they be of the same optical density and viewed on the same lightbox. Please refer to Chapter Three for further information about viewing conditions.

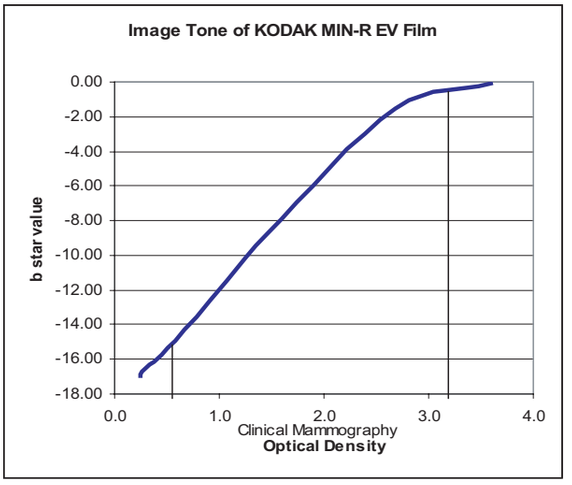
Factors affecting image tone:

- The structure of the film (morphology of developed silver grain, support density)
- The developer formulation and condition can effect silver morphology (Refer to Processing Section for further information)
- Type and condition of fixer
- Temperature of water (wash and mixing)
- Please refer to Chapter Two, processing for additional information.

Troubleshooting image tone concerns

- Determine if the complaint is tone, dye stain or contrast.
- Examine phantom images over time
- Review the processing conditions
  - chemistry type, properly mixed, fresh or oxidized
  - replenishment rates
  - developer, fix and wash water temperature
  - chemistry mixing temperature
- Ensure that optical density matches between the previous and present clinical images when comparing tone. If optical density has increased, images will appear warmer in tone. This is a characteristic of all silver halide films.
- Chemistry analysis may be helpful when chemistry is suspect.

Tone versus optical density



**approximate tone measurement from a single emulsion of MIN-R EV film*

**MIN-R EV film was processed in a KODAK X-OMAT 5000 RA Processor, KODAK X-OMAT EX II Developer and KODAK RP X-OMAT LO Fixer; setup according to Service Bulletin 30*

Information Needed by Kodak to Facilitate Troubleshooting

When contacting Kodak for assistance with image quality concerns, having as much of the following information as possible will facilitate all trouble-shooting efforts:

Facility name: _____

Contact: _____

Phone: _____

Film Distributor: _____

Processor maintenance performed by:

_____

Kodak Account Manager and/or Film Systems Specialist: _____

BEST PRACTICE

Benchmark information from conversion to MIN-R EV

- Sensitometric strip from day aims established
- Phantom Optical Density
- Clinical Images:
  - Patient ID # of optimized Fatty
  - 50% Glandular
  - Glandular

Describe the Problem/Concern/Change:

When did the problem/concern/change start: _____

Emulsion Number: _____

Log kept? Y N

If a QC Problem

- Film Volume: _____
- Any recent workload or chemistry changes: _____

Chemistry

- Developer Type: _____
- Fixer Type: _____
- Date Developer and/or Fixer last changed: _____
- Starter Volume added: _____
- Replenishment rates:
  Developer: _____
  Fixer: _____

  Any Recent changes? _____
- 21 Steps from Sensi strip (before and after change) _____
- H&D curve available? _____

If a phantom concern

- Optical Density:
  Split Phantom Done? Y N

  Optical density Previous emulsion

  _____

  Present emulsion

  _____

If a Tone Concern

Type of Developer and Fixer in Use:

Any Recent change in manufacturer or type of chemistry used? _____

_____

- Replenishment Rate: _____
- Water Temperature: _____
- Film optical density from phantom:
  Present_____ Previous_____
- Viewing condition changes? Y N

  If Yes, explain _____

  _____

If an Artifact Concern

- Plus Density Y N
- Minus Density Y N

  Grease Pencil
  Test Performed Y N

  Results: _____
- Randomly Occurring Y N
- Processor:
  Type: _____
  Temperature: _____
  Developer: _____
  Fixer: _____
  Wash: _____
- Processor Maintenance
  Venting Checked
  since install? Y N

  If not ok, corrective action: _____

  _____
- Chemistry: _____
- Developer Type: _____
- Fixer Type: _____
- Replenishment rates:
  Developer: _____
  Fixer: _____

  Mixing Method:
  Manual Automixer Pre-mix

Screens/Cassettes

- Type of Cassettes:
  MIN-R 2 MIN-R
- Type of Screen:
  MIN-R EV 150 MIN-R EV 190
  MIN-R 2000 MIN-R 2190
  MIN-R

Minus Density or Stains

- Type of Cleaner used:
  MIN-R Screen Cleaner
  Other: Please Specify: _____
- Type of Wipe Used:
  MIN-R Screen Cleaner Wipe
  Other: Please specify: _____
- Frequency of Cleaning: _____
- Screen Film Contact: _____
- Screens fully cleaned prior to test? Y N
- Any areas larger than 1 cm? Y N
- If Yes was test repeated? Y N
- Did the location of the spots change? Y N

Screen Film Uniformity

- Form available _____
- Type and sizes isolated _____

© Eastman Kodak Company 2002-4

Quick reference guide:

Mammographic x-ray units should be calibrated for the MIN-R EV system by qualified service personnel.

Optical density:

- For MIN-R EV film, the recommended optical density range is between 1.4 and 1.8 (good trade-off between exposure times, viewing conditions and film contrast).
- Depends heavily on viewing conditions, observer preferences, film screen combination.
- Higher optical density (1.7-1.8)
  - Optimum viewing conditions:
    - Bright viewboxes
    - Masking
    - Ambient light controlled
  - Increases exposure time
    - Motion blur could result
  - Fatty tissue may be overexposed with reduced contrast
  - Tone may be warmer/browner
  - Refer to gamma chart on page 89
- Lower Optical Density (<1.4)
  - Glandular tissue underexposed
    - Abnormalities may not be visualized
    - Tissue appears lower contrast
    - Refer to gamma chart on page 89
- Please refer to Chapter 3, Optimizing Exposure

kVp

- Lower kVp will increase subject contrast, higher kVp will reduce subject contrast.
  - The use of the high contrast Min-R EV film may balance this.
- Lower kVp will increase exposure time and patient dose; higher kVp will shorten exposure time and decrease patient dose.
- kVp should be as low as possible to achieve the desired optical density and keep the exposure time reasonable (between 0.5 and 2.0s) depending on breast composition and thickness.
- A general rule of thumb would be low kVp (24-27) for thinner fatty breasts and higher kVp (27-31) for thicker dense breasts.

Anode/filter

- Selection of anode/filter combination should be made according to breast thickness and composition:
- Mo-Mo is reasonable for most thinner fatty breasts.
- Rh anodes and filters should be considered for thicker denser breasts in order to shorten exposure times.

Exposure time

- Exposure times that are too short may not be reproducible and image consistency will not be maintained. Images may appear noisy.
- Exposure times that are too long (>2.0s in an average breast) increase patient dose and may lead to motion blurring
- To reduce exposure time consider raising kVp (or lowering optical density).

Exposure modes

- Most machines offer timed automatic exposure mode where the operator selects kVp and filtration and the exposure is controlled for the time the x-rays are on.

Some machines will have other automatic modes in which kVp and filtration can also be selected automatically. If this mode of operation is used, the operator should monitor the kVp and filtration selection. The automatic algorithm should not select the higher kVps or Rh anodes and filtrations except in very thick and dense breasts (see tips above). The x-ray equipment manufacturer should be consulted to ensure that the automatic algorithms match the preferences of the facility.

Understanding Automatic Exposure Control

It is difficult to determine breast composition by breast thickness. Manual selection of technique factors can result in mammograms of under or over exposure as well as poor contrast. Properly calibrated AEC will automatically select all or some of the technique factors which will produce more consistent images.

Types of AEC

Manually select kVp, anode and filter	AEC will select mAs
Manually select kVp	AEC will select mAs, anode and/or filter
AEC will select all technique factors	kVp, mAs, anode, filter

NOTE: *If the automatic exposure control is operating and has been calibrated correctly, the optical density should be consistent when technical factors change,* i.e., kVp ↑ mAs ↓ = OD = kVp ↓ mAs ↑

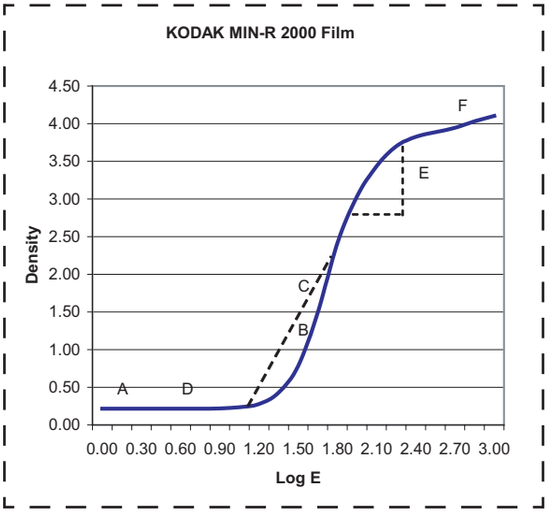
Parameter				Subject Contrast	O.D.	Dose	Possible Issue
Anode	Filter	kVp	mAs				
Mo	Mo	↓	↑	↑	=	↑	Motion blur/black/white
Mo	Mo	↑	↓	↓	=	↓	Grey/flat
Mo	Rh	↑	↓	↓↓	=	↓↓	Flat, Noise ↑
Rh/Wo	Rh	↑	↓	↓↓↓	=	↓↓↓	Noise ↑ , grey, more skin line

Caution: Grid lines can occur if exposure time is too short.

Chapter 6: Processing MIN-R 2000 Film

Throughout this guide we will be relating changes in daily process control numbers caused by: the type of processor, inappropriate time in solutions, developer temperature, oxidation and over or under replenishment, to possible effects on the sensitometric curve and the clinical image.

Please note that the sensitometric data contained in this guide is applicable only when using KODAK MIN-R 2000 Film with properly mixed solutions of KODAK chemistries recommended for mammography. If using another manufacturer's chemistry, it is recommended that similar information be requested from that manufacturer.

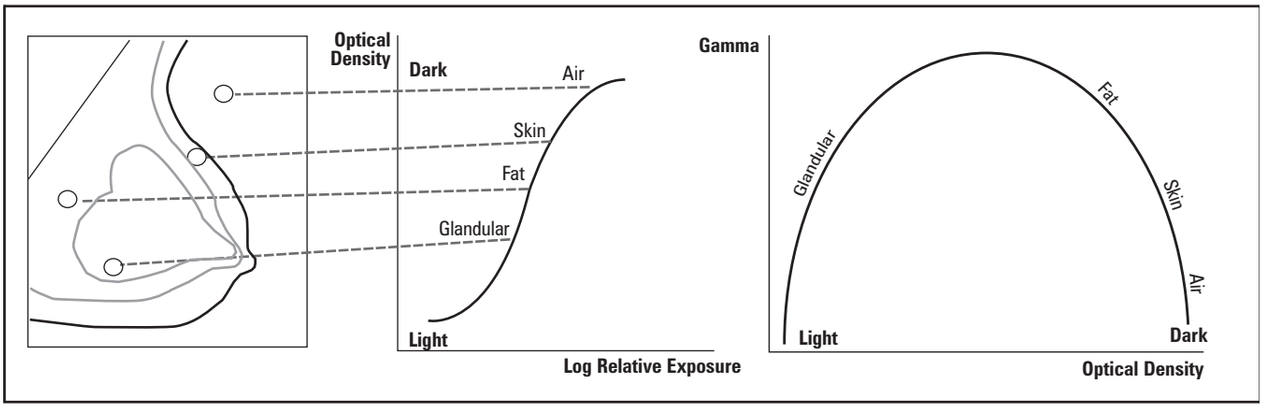


Legend

A = Fog
B = Speed
C = Mid-scale Contrast or Average Gradient
D = Toe (Whites)
E = Shoulder Contrast
F = D-Max

Sensitometric Curve KODAK MIN-R 200 Film processed in KODAK RP X-OMAT Developer and KODAK RP X-OMAT LO Fixer in a KODAK X-OMAT 480 RA Processor.

Changes in these parameters (Base + Fog, Speed, Mid-scale Contrast, Toe, Shoulder and D-Max) can directly affect the clinical image as illustrated in the chart below. It is always important to validate changes in sensitometry or process control to the phantom or clinical image quality.



Processor Recommendations

The size of the developer and fixer tanks as well as the roller configurations can affect the performance of mammography film as illustrated in the table below for a typical mammography film.

	Large Tank (5000 RA, 480 RA, 460 RA, M6B)	Medium Tank (MIN-R Mammography, 3000 RA, 270 RA, M35M)	Shallow Tank (X-OMAT 1000 Medical X-Ray)
Speed	=	"="	↓↓
Contrast	=	"="	↓↓↓↓
D-Max	=	"="	↓↓↓↓↓↓
Image Tone	=	"="	↓
Dye Stain	=	"="	=
Artifacts	=	↓ (plus density artifacts processed primary emulsion side up)	↓↓↓↓*

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.
Contrast: ↑ is a 0.10 change in average gradient
D-Max: ↑ is 0.10 change in optical density
"=" is the baseline.
*plus density artifacts when processed emulsion side up in X-OMAT 1000, and both emulsion side up and down in the Medical X-Ray processor.
We do not recommend processing MIN-R 2000 film in shallow tank processors.

Set Up

Developer Processing Time and Temperature

- KODAK MIN-R 2000 Film should be processed using a standard processing cycle; developer immersion time and developer temperature should be as specified by the processor manufacturer as equivalent to a standard cycle.
  - Note that decreased, not increased, contrast will result if extended cycle processing is employed.
  - The table below reflects standard cycle processing parameters for KODAK X-OMAT Processors; for other brands of processors, check with the manufacturer to ensure use of a standard cycle.

KODAK X-OMAT Processor(s)	Developer Immersion Time (Approximate)	Developer Temperature
MIN-R Mammography, and M35M and M35A-M	33 seconds	92°F (33.5°C)
M7[1] and M7A[1]	31 seconds	92°F (33.5°C)
M7[2]. M7A[2]. M7B, 270 RA, 3000 RA; XML 300, XML 300 Plus, XML 7000	27 seconds	94°F (34.4°C)
M6B, M6-N, M6A-N, M6AW, M6R, 460 RA, 480 RA and 5000 RA	25 seconds	95°F (35°C)
M8	21 seconds	96°F (35/6°C)
[1] KODAK X-OMAT M7 and M7A Processors with 140-second total processing time		
[2] KODAK X-OMAT M7 and M7A Processors with 122-second total processing time		

How Different Processing Times Affect MIN-R 2000 Film

Due to the pure AgBr grains, the contrast, toe and D-Max of KODAK MIN-R 2000 Film are relatively insensitive to small changes in developer time and temperature.

Sensitometric Parameter	Transport Speed (inches/minute)		
	34 inches/min (Ext'd Cycle)	66 inches/min (Standard Cycle)	99 inches/min (Rapid Cycle)
Speed measured at 1.0 above B+Fog	↑↑↑↑↑	"="	↓↓↓↓↓↓
Contrast (Average Gradient or Contrast Index) (Mid-scale)	"="	"="	"="
Toe Contrast (Whites)	"="↓	"="	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	½↓	"="	↓↓½
D-Max (Darkest)	"="	"="	"="
Drying	↑	=	"="

Please note that MIN-R 2000 is not recommended for rapid cycle processing.

Testing was done in a KODAK X-OMAT 460 RA Processor with a developer temperature of 95°F (35°C).

Speed : ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above B+ Fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density

"=" is baseline

Drying ↑ is improved, ↓ is worse

Developer Temperature Sensitivity

As is illustrated in the chart below, the contrast of MIN-R 2000 film decreases slightly with increased temperatures.

Sensitometric Parameter	Developer Temperature		
	91°F (32.8°C)	95°F (35°C)	99°F (37.2°C)
Speed measured at 1.0 above B+Fog	↓↓↓↓↓↓	"="	↑↑↑↑↑↑
Contrast (Average Gradient or Contrast Index) (Mid-scale)	"="	"="	↓
Toe Contrast (Whites)	"="	"="	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	½↓	"="	½↓
D-Max (Darkest)	↓	"="	½↑

Processed in a KODAK X-OMAT 460 RA Processor

Speed: ↑ is 2.5% change in optical density at the speed point when measured at 1.0 above B+ Fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder Contrast: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density.

95°F (35°C) is the baseline for comparison.

Please note that similar results would be seen in other processors varying plus or minus four degrees from the processor manufacturer's recommended developer temperature for the standard cycle. It is therefore important to follow the manufacturer's recommendations for developer temperature.

Monitoring and Maintenance

To monitor that the processor is consistent, quality control (sensitometry) must be performed.

For best results be sure to follow a regular preventive maintenance schedule. It may be beneficial to keep a processor maintenance log with your quality control log.

A Method for Evaluating Film Performance in Other Manufacturer's Developer Solutions

Please refer to pp. 28-29 of this guide for a method of evaluating film performance in other manufacturers' developer solutions.

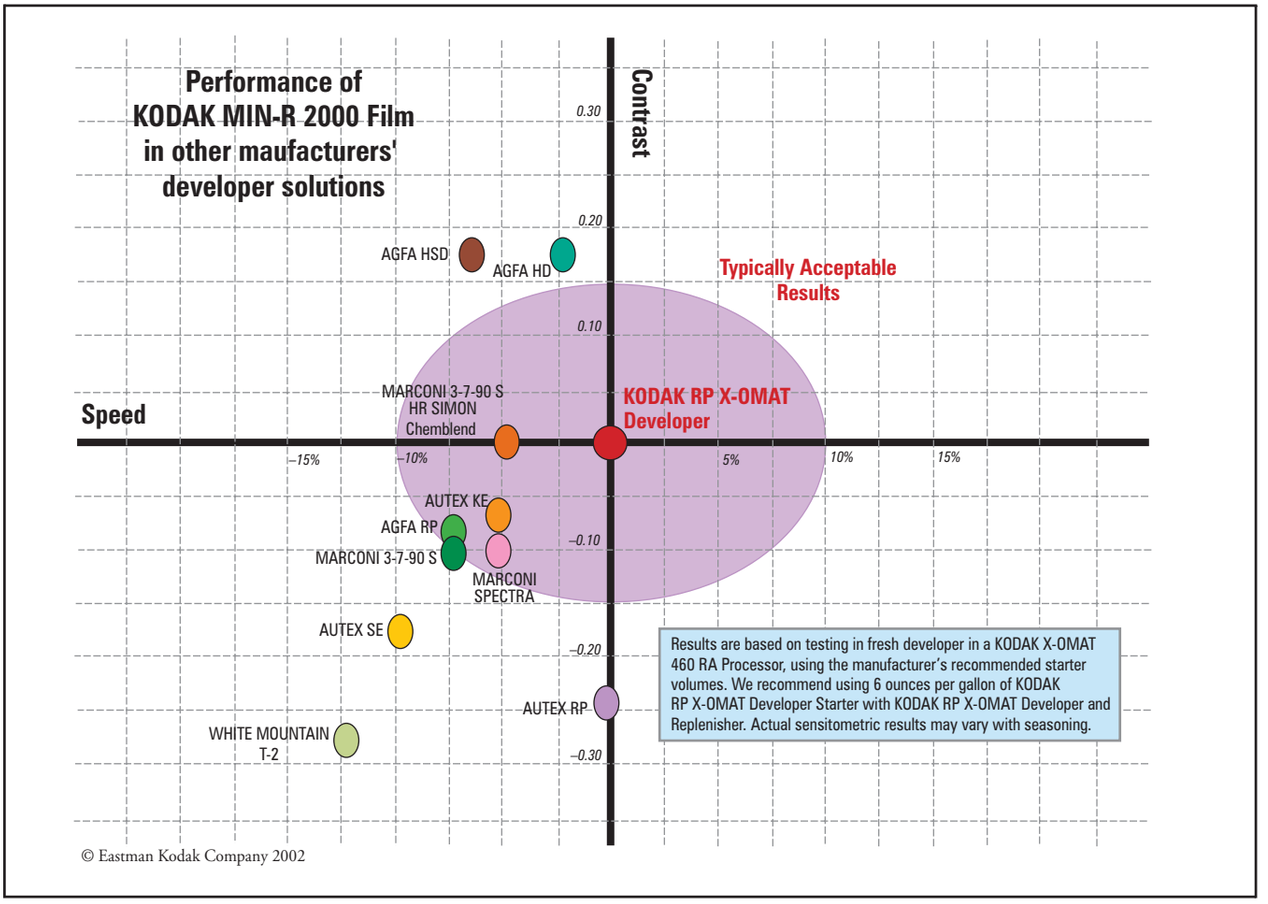


Figure 1 Typical results versus KODAK RP X-OMAT Developer

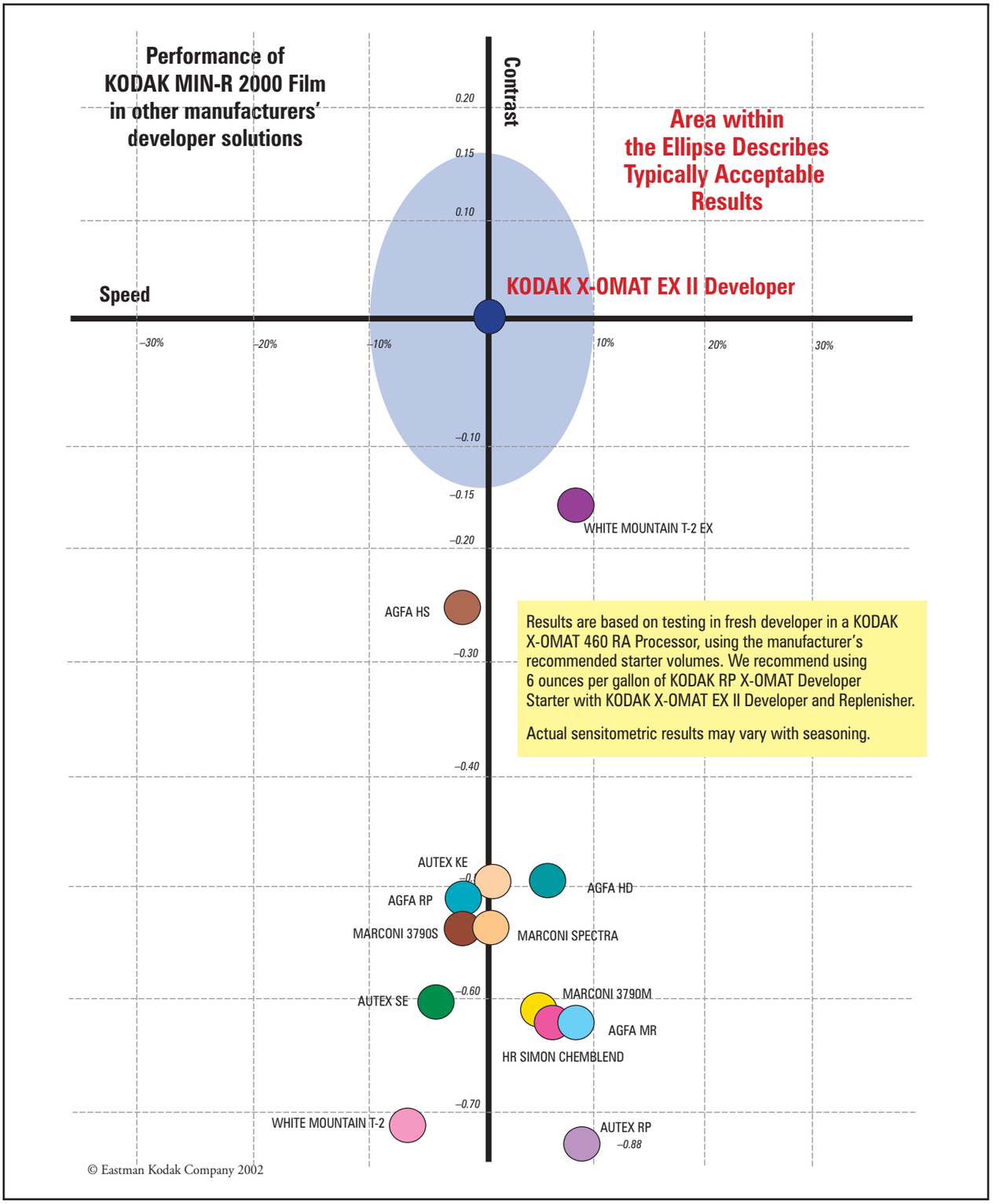


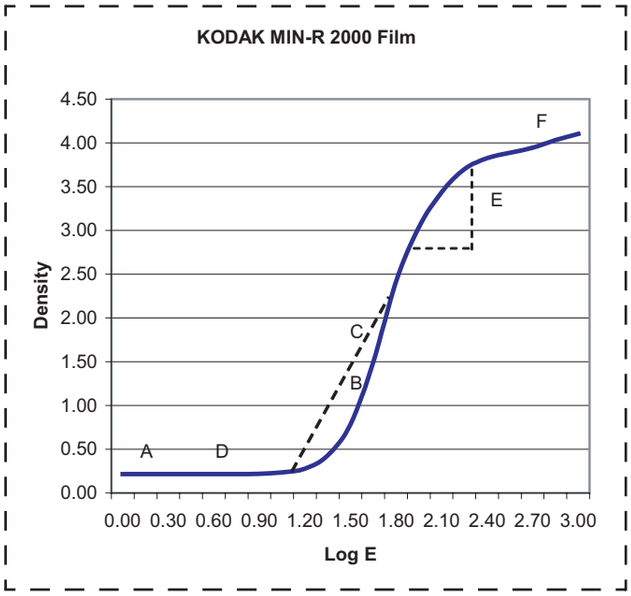
Figure 2 Typical Results versus KODAK X-OMAT EX II Developer

Starter

For MIN-R 2000 film, the addition of 50 milliliters per liter or six ounces per U.S. gallon (3.8 liters) of KODAK RP X-OMAT Developer Starter is required to achieve appropriate image quality in a processor dedicated to MIN-R 2000 Film. As per the September 2001 revision of Service Bulletin No. 30 (see Appendix), the addition of 25 milliliters per liter or three ounces per U.S. gallon (3.8 liters) of KODAK RP X-OMAT Developer Starter is recommended for non-dedicated environments.

Over and Under Use of Starter

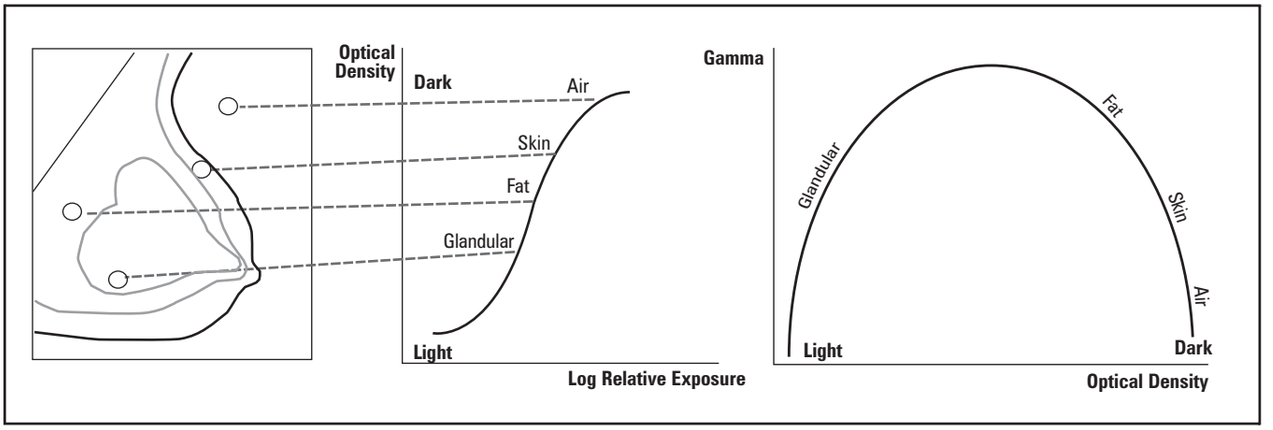
While the effects of over-and under-use of starter varies by film type as well as by different brands of starter, in general for some mammography films, not using starter will result in an increase in speed and D-max and a decrease in contrast on the H&D curve as well as the clinical image. Adding too much starter may also change speed, contrast and D-Max.



Legend

A = Base + Fog
B = Speed Point
C = Mid-scale Contrast or Average Gradient
D = Toe (Whites)
E = Shoulder Contrast
F = D-Max

Sensitometric Curve KODAK MIN-R 2000 processed in KODAK RP X-OMAT Developer and KODAK RP X-OMAT LO Fixer in a KODAK X-OMAT 480 RA Processor.



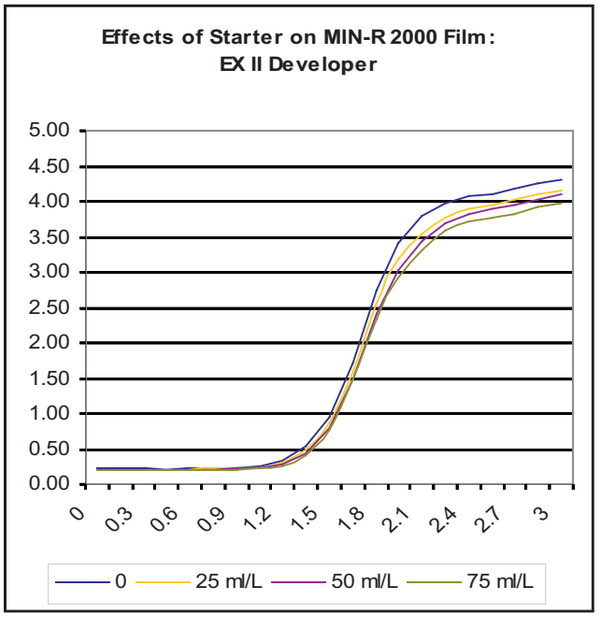
Effects of Starter on KODAK MIN-R 2000 Film in KODAK RP X-OMAT Developer			
Parameter	No Starter	25 ml/L or 3 ounces/ gallon Starter	50 ml/L or 6 ounces/ gallon Starter
Fog	"="	"="	"="
Speed measured at 1.0 above B+Fog	↑↑↑↑	"="	"="
Contrast (Average Gradient or Contrast Index) (Mid-scale)	↓↓↓↓	↓↓	"="
Toe Contrast (Whites)	↓↓	↑↑	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑↑↑	↑↑↑↑	"="
D-Max (Darkest)	↑↑	↑	"="

Baseline is 50 ml/L or 6 ounces/gallon Starter

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

D-Max: ↑ is 0.10 change in optical density



Effects of Starter on KODAK MIN-R 2000 Film in KODAK X-OMAT EX II Developer			
Parameter	No Starter	25 ml/L or 3 ounces/ gallon Starter	50 ml/L or 6 ounces/ gallon Starter
Fog	"="	"="	"="
Speed measured at 1.0 above B+Fog	↑↑↑↑	↑	"="
Contrast (Average Gradient or Contrast Index) (Mid-scale)	↓↓↓↓↓↓	↓↓	"="
Toe (Whites)	↓↓½	↓	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑↑	↑↑↑	"="
D-Max (Darkest)	↑	½ ↑	"="

Baseline is 50 ml/ L or 6 ounces/gallon Starter

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

D-Max: ↑ is 0.10 change in optical density

Toe Contrast: ↑ is 0.05 change in Toe Contrast

Summary: Speed decreases with the addition of starter. Contrast increases with additional starter.

Recommended starting points for developer and fixer replenishment rates and starter volumes for MIN-R 2000 film are published in Service Bulletin No. 30 (included separately). As illustrated in the charts below, over-replenishing with MIN-R 2000 film may result in decreased contrast. Under-replenishment will result in lower speed and D-Max, and a browner image.

MIN-R 2000 Film Response to Seasoning, Over and Under Replenishment KODAK RP X-OMAT Developer and RP X-OMAT LO Fixer				
Parameter	**Over-replenished**	**Normal Starter**	**Normal Seasoning**	**Under-replenished**
Fog	=	=	=	=
Speed (measured at 1.0 above B+Fog)	↑	=	=	↓↓
Contrast (Average Gradient or Contrast Index) (Mid-scale)	↓↓	=	=	"="
Toe Contrast (Whites)	↓	=	"="	"="
Shoulder Contrast ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑↑↑	=	↑↑	↑
D-Max (Darkest)	↑	=	↑	↓
Image Tone ↑ bluer ↓ browner/warmer	"="	=	↓	↓
Dye Stain ↓ (lower=bluer) Mainly visible on QC film	"="	=	"="	"="

Processed in a KODAK X-OMAT 460 RA Processor

"=" is equivalent to results obtained with "Normal" starter

"Normal" Starter (6 ounces/gallon KODAK RP X-OMAT Developer Starter) is the baseline.

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder Contrast: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density

MIN-R 2000 Film Response to Seasoning, Over and Under Replenishment KODAK X-OMAT EX II Developer and RP X-OMAT LO Fixer				
Parameter	**Over-replenished**	**Normal Starter**	**Normal Seasoning**	**Under-replenished**
Fog	=	=	=	=
Speed (measured at 1.0 above B+Fog)	↑	=	=	↓↓↓
Contrast (Average Gradient or Contrast Index) (Mid-scale)	↓↓	=	"="	↓
Toe (Whites)	↓	=	"="	"="
Shoulder ↑ Increased shoulder contrast/ (less skin line or breast periphery) ↓ More visible skinline	↑↑↑	=	=	=
D-Max (Darkest)	↑	"="	"="	"="
Image Tone ↑ bluer ↓ browner/warmer	↑	=	"="	↓
Dye Stain ↓ (lower=bluer) Mainly visible on QC film	"="	=	"="	"="

Processed in a KODAK X-OMAT 460 RA Processor

"=" is equivalent to results obtained with "Normal" starter

"Normal" Starter (6 ounces/gallon KODAK RP X-OMAT Developer Starter) is the baseline.

Speed: ↑ is a 2.5% change in optical density at the speed point when measured at 1.0 above b+fog.

Contrast: ↑ is a 0.10 change in average gradient

Toe: ↑ is a 0.05 change

Shoulder Contrast: ↑ is a 0.2 change

D-Max: ↑ is 0.10 change in optical density

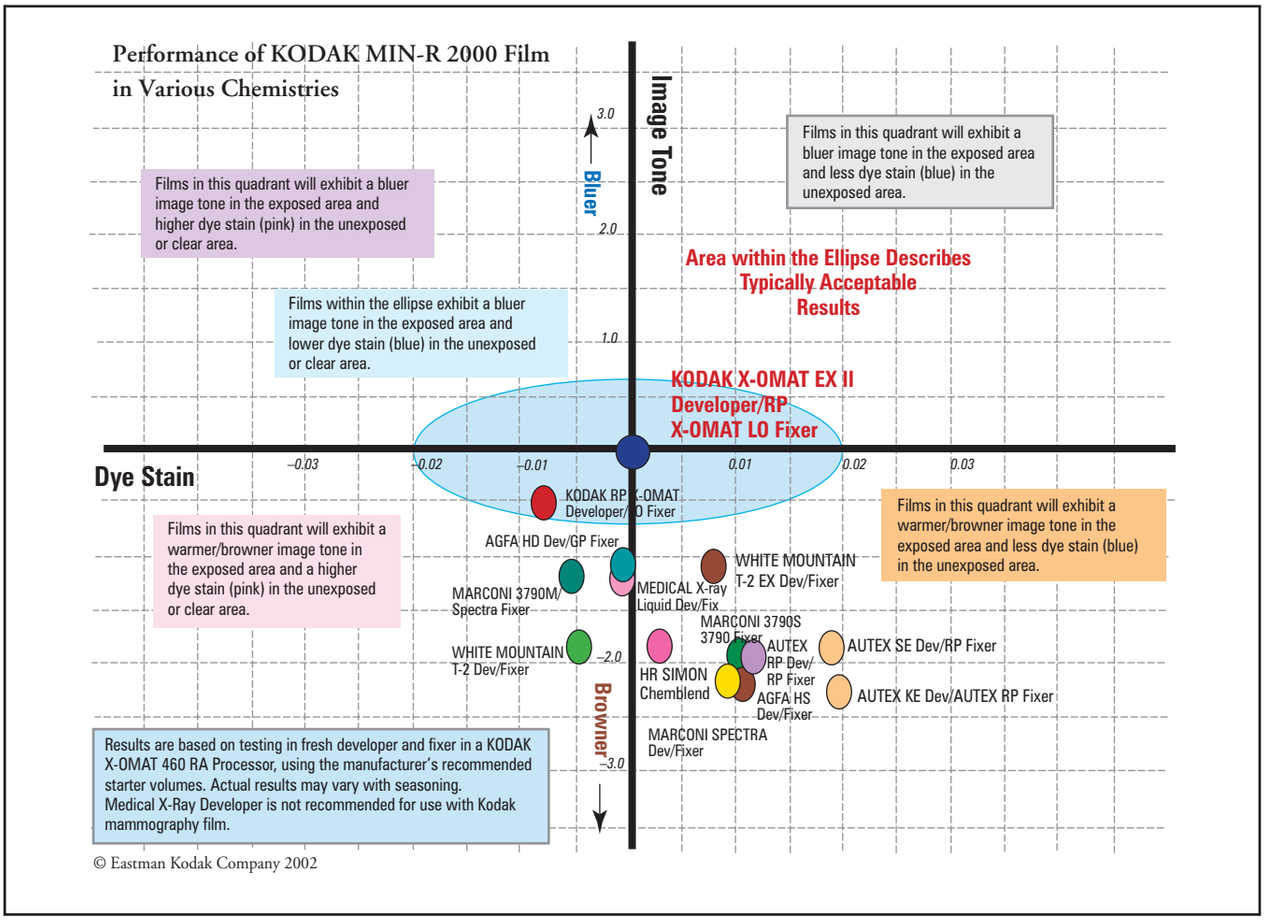
Caveat

- Assumes the replenishment rates are set accurately and, if in a RA processor, that the rates are appropriately calibrated.

Summary: Over-replenishment will increase process control speed and decrease contrast while under-replenishing will decrease D-Max. Since the "seasoning" effects are small, it is not necessary to retain the developer when routine processor maintenance is performed on the processor.

A Method for Evaluating Film Performance in Other Manufacturers' Developer and Fixer Solutions for Image Tone and Dye Stain

Please refer to pp. 40-41 for a method to evaluate film performance in other manufacturers' developer and fixer solutions.


Performance of KODAK MIN-R 2000 Film in Various Chemistries
Image Tone
3.0
Bluer
2.0
1.0
Films in this quadrant will exhibit a bluer image tone in the exposed area and higher dye stain (pink) in the unexposed or clear area.
Films in this quadrant will exhibit a bluer image tone in the exposed area and less dye stain (blue) in the unexposed area.
Area within the Ellipse Describes Typically Acceptable Results
Films within the ellipse exhibit a bluer image tone in the exposed area and lower dye stain (blue) in the unexposed or clear area.
KODAK X-OMAT EX II Developer/RP X-OMAT LO Fixer
–0.03
–0.02
–0.01
0.01
0.02
0.03
Dye Stain
KODAK RP X-OMAT Developer/LO Fixer
Films in this quadrant will exhibit a warmer/browner image tone in the exposed area and a higher dye stain (pink) in the unexposed or clear area.
AGFA HD Dev/GP Fixer
WHITE MOUNTAIN T-2 EX Dev/Fixer
Films in this quadrant will exhibit a warmer/browner image tone in the exposed area and less dye stain (blue) in the unexposed area.
MARCONI 3790M/ Spectra Fixer
MEDICAL X-ray Liquid Dev/Fix
MARCONI 3790S 3790 Fixer
AUTEX RP Dev/ RP Fixer
AUTEX SE Dev/RP Fixer
WHITE MOUNTAIN T-2 Dev/Fixer
–2.0
HR SIMON Chemblend
AGFA HS Dev/Fixer
AUTEX KE Dev/AUTEX RP Fixer
Browner
–3.0
MARCONI SPECTRA Dev/Fixer
Results are based on testing in fresh developer and fixer in a KODAK X-OMAT 460 RA Processor, using the manufacturer's recommended starter volumes. Actual results may vary with seasoning. Medical X-Ray Developer is not recommended for use with Kodak mammography film.
© Eastman Kodak Company 2002

©Eastman Kodak Company 2002

D. Drying

Drying prepares the film for handling, viewing, and storage by removing excess water and is the last stage of hardening. The physical characteristics of KODAK MIN-R 2000 Film should allow for good drying.

Factors that Affect Drying

- Processor design
- Venting
- Temperature
- Humidity
- Quality of chemistry
- Film volume (i.e., serial unload, batch processing)

A blower in the processor supplies heated air to the dryer section. Most of the warm air is recirculated; the rest is vented to prevent buildup of excessive humidity in the dryer.

Proper processor ventilation is important to achieve proper film drying and decrease surface-pattern, or drying, artifacts. Refer to: Service Bulletin No. 101 (October 1992), *Dryer Venting Requirements for All KODAK X-OMAT Processors,* publication No. N-923. (Technical Information Bulletin 3111 may be found in the Appendix.)

Venting:

Excessive ventilation results in high evaporation rates and oxidation of the developer. This often seems to correlate with soft shoulder (skin line and breast periphery visibility) and non-uniform development issues.

Under-ventilation tends to result in condensation related problems and often low level fixer contamination in the developer.

Pressure imbalance in through-the-wall installations is also a concern and may result in similar problems. High pressure on the feed side of the processor acts like over-ventilation, lower pressure on feed side of wall acts like under-ventilation.

Information Needed When Troubleshooting

Prior to troubleshooting and/or changing anything in the Imaging Chain, it is important to determine if the concern is with the QC charts, phantom charts or clinical image or any combination thereof.

When troubleshooting, it is important to have a known optimized point of comparison. For this reason it is helpful to retain the initial QC film, phantom and log of initial patient images as a reference or benchmark when first converting to MIN-R 2000 film.

Trends in QC Charts

What is a trend?

A trend is any deviation in the same direction from the established aim for longer than three days.

When Mid Density (MD) or Speed Index (SI), Density Difference (DD) or Contrast Index (CI), and Base + Fog (B + F) differ greatly from expected values and/or indicate an out-of-control processing environment (e.g., reaching or exceeding ±0.15 of the operating levels for MD and DD), always generate another sensitometric strip, making sure that:

- The emulsion side of the film was toward the light source of the sensitometer.
- The temperature of the developer solution in the processor has stabilized before exposing and processing the sensitometric strip.
- The settings on the sensitometer were properly set (i.e., single-sided exposure for single emulsion films, double-sided for double-sided films, appropriate spectral sensitivity (green or blue), recommended DIP switches if the sensitometer is exposure adjustable, etc.).
- The film used was taken from the box set aside for processor quality control.
- The delay between exposing and processing the film is as normally occurs from day to day. (Note that immediate processing after exposure of the sensitometric strip by the sensitometer is recommended.)
- The same densitometer was used to measure MD, DD, and B + F values.
- The calibration of the densitometer is correct.
- If an automatic scanning densitometer is used, the correct channel was used and the programming has not been changed.
- *It may be recommended to expose another phantom image at normal settings and determine if the same trend visible on the QC chart is also visible on the phantom's background density and density difference.*

Please Note:

- If the numbers are out of limits, adding additional starter or partially filling the developer tank with fresh developer is not recommended.
- **Retaining the developer solution after a processor maintenance is not required.**

Compare MD, DD, and B + F results from the processing control chart to the information below to determine possible causes and corrective actions.

Trends in Graph	Possible Causes	Corrective Actions
MD: ↓ DD: ↓ B+F: →	Severe under-replenishment	• Check developer replenishment rate • Check that rate is set as recommended in Service Bulletin No. 30 • Check for kinked or air-locked developer replenishment line • Check for improperly mixed (over diluted) developer replenisher • Check amount of water added • Check chemical usage • Check for change in film volume since rate was set and adjust accordingly (raise) • Communicate changes in film volume to processor service firm
MD: ↓ DD: ↓ B+F: ↑ or →	Severe Contamination of developer with fixer	• Call service to clean the processor • Drain developer tank • Thoroughly flush tank and developer rack with water • Change the developer filter • Use splash guards • Remove and insert the fixer rack carefully • Process films with edges in contact with film feed tray guides to avoid film jam
MD: ↓ DD: ↓ B+F: →	Severe oxidation of developer	• Always use a floating lid on top of the developer replenisher inside the holding tank • Check the developer replenishment rate • Call service to check the processor
	Exhausted developer	• Check developer replenishment rate • Check that rate set as recommended in Service Bulletin No. 30 • Check chemical usage • Check for change in film volume since rate was set and adjust accordingly • Communicate changes in film volume to processor service firm • Check processor ventilation
MD: ↓ DD: ↓ B+F: ↑	Expired film	• Check film expiration date • Manage film inventory using first-in, first-out method
	Film stored above the recommended temperature and relative humidity	• Store unprocessed/unexposed film and processed radiographs between 50 to 70°F (10 to 21°C) and 30 to 50% relative humidity

Trends in Graph	Possible Causes	Corrective Actions
MD: ↑ DD: ↓ B+F: ↑ or →	Over-replenishment	• Check Service Bulletin No. 30 for recommended rates and adjust accordingly
	No starter added to fresh developer in processor developer tank	• Check Service Bulletin No. 30 for the amount recommended for chemistry, film and processor in use • Add the correct amount of KODAK RP X-OMAT Developer Starter
	Insufficient amount of starter added to fresh developer	• Add the correct amount of KODAK RP X-OMAT Developer Starter
	Safelight Fog	• Perform darkroom fog test
MD: ↑ DD: ↑ B+F: →	Slight Contamination of developer with fixer	• Call service to clean the processor • Drain developer tank • Thoroughly flush tank and developer rack with water • Change the developer filter • Use splash guards • Remove and insert the fixer rack carefully • Process film with edges in contact with film feed tray guides to avoid film jams
MD: ↑ DD: ↓ B+F: ↑ or →	Developer temperature higher than recommended (within 5°F [3°C])	• Measure developer temperature using accurate or calibrated thermometer • Verify developer temperature set as recommended in Service Bulletin No. 30 for model of processor • Lower thermostat to correct temperature • Check thermostat to correct temperature • Check water flow and temperature
	Water temperature higher than recommended (if developer temperature set above set point)	• Check temperature of incoming water • Verify water temperature set as recommended in Service Bulletin No. 30 for model of processor • Install mixing valve to regulate water temperature
	Developer time longer than recommended	• Check immersion time using time-in-solution test tool

Trends in Graph	Possible Causes	Corrective Actions
MD: ↓ DD: → or ↓ B+F: →	Developer temperature lower than recommended (within 5°F [3°C])	• Measure the developer temperature using accurate or calibrated thermometer • Verify developer temperature set as recommended in Service Bulletin No. 30 for model of processor • Raise thermostat to correct temperature • Check thermostat and recirculation pump for malfunction • Check water and temperature
	Water temperature lower than recommended (if developer temperature below set point)	• Check temperature of incoming water • Verify water temperature set as recommended in Service Bulletin No. 30 for model of processor • Install mixing valve to regulate water temperature
	Developing time shorter than recommended	• Check immersion time using time-in-solution test tool
MD: ↓ DD: ↑ B+F: →	Too much starter added to fresh developer (>50 percent)	• Check Service Bulletin No. 30 for the amount recommended for the model of processor in use. • Add the correct amount of KODAK RP X-OMAT Developer Starter

Conversion Instructions and Processing Recommendations

For KODAK MIN-R 2000 Film for Mammography

Supercedes Conversion Instructions and Processing Recommendations for KODAK MIN-R 2000 Film for Mammography, SB-244 (Sept. 1997)

For Internal Kodak and Authorized Distributor Use Only

MIN-R 2000 Mammography Film

- MIN-R 2000 has a single-emulsion design, for use with standard, green-emitting single screen cassettes.
- MIN-R 2000 is identified by a double V-notch. The emulsion is up when the notch is on the right hand side at the top edge of the film. The emulsion should be in contact with the screen during imaging.

Changes from the 1997 edition:

- Includes KODAK X-OMAT EX II Developer and Replenisher
- Updated recommendations on flooded replenishment
- Recommendations for
  - KODAK X-OMAT 3000 RA Integrated Processor for X-OMAT Multiloader 300 Plus and X-OMAT Multiloader 7000
  - KODAK MIN-R Mammography Processor
  - KODAK Miniloader 2000P
  - Specific Gravity of KODAK processing solutions recommended for mammography

Objectives Of The Conversion Guide

- Establish/verify correct processing parameters for KODAK MIN-R 2000 Film
- Establish quality control aims
- Establish initial image quality parameters
- Verify other Quality Control tests

Tools Required:

- Sensitometer capable of producing 21 steps
- Densitometer capable of spot reading
- Thermometer
- Curve plotting paper (KODAK Publication # M3-58, Cat # 841 2843) or scanning densitometer
- 4-5 cm Lucite or BR 12 tissue equivalent phantom (RMI 156, Nuclear Associates 18-220)

Reference Material:

- *KODAK MIN-R 2000 Film System User Guide* (KODAK Publication # M3-108, Cat # 193 9826)
- *Service Bulletin No. 30*, revised January 2004
- Mammography Quality Control Manual 1999, ACR

PROCESSORS

KODAK MIN-R 2000 Film is designed for standard cycle processing. All KODAK X-OMAT Processors should be adjusted to comply with the standard cycle processing parameters listed in the film processing instructions for that specific processor.

NOTE: *The KODAK Medical X-Ray, X-OMAT M43, M43A, Clinic 1, X-OMAT 1000, M35A, M35 and X-OMAT 2000 and 2000 A Processors are not recommended for processing KODAK MIN-R 2000 Film (or other KODAK Mammography Films). Other manufacturers' processors with shallow developer tanks or short developer racks may not produce optimum results if used to process KODAK MIN-R 2000 Film. Consult the processor manufacturer recommendations for standard cycle processing set-up.*

KODAK 460 RA, 480 RA, and 270 RA Processors:

a. On the Display Panel, select the "STD Cycle" key for standard cycle processing.
b. Check that all settings are set for standard cycle default values.
c. Process KODAK MIN-R 2000 Film emulsion side up.

Note:

- Upgraded software is required if processing fewer than 260 18 x24 cm size sheets (or equivalent) per 8 hour shift unless the Processor is operating in the flooded replenishment mode. If needed, order the appropriate Disk or PROM set.

Processor	Disk* (there is no charge)	PROM Set (there is a charge)	Version Number
270 RA	9B8537	9B8533, except Japan	3.0
		9B8535, Japan	
460 RA	9B8530	9B8526, except Japan	3.0
		9B8528, Japan	
480 RA	8B7098	8B7094, exept Japan	3.0
		8B7095, Japan	

* Laptop required for software download of disk, or install new PROM set.

No additional changes are necessary subsequent to the installation of the new software.

KODAK X-OMAT 3000 RA (Stand-Alone) and 5000 RA Processors:

a. On the Display Panel, select the "STD Cycle" key for standard cycle processing.
b. Check that all settings are set for standard cycle default values.
c. Process KODAK MIN-R 2000 Film emulsion side up.

Note:

- You will need to enable a special feature in the software if processing fewer than 260 sheets per 8 hour shift, unless the Processor is operating in the flooded replenishment mode. See the procedure below.
- This special feature is only available in software Version 3.0 or higher for both the 3000 RA and 5000 RA processors. If necessary, order:

Processor	Disk* (there is no charge)	PROM Set (there is a charge)	Version Number
3000 RA	9B6721	not available	3.31
5000 RA	9B8204	not available	4.15

*Laptop required for software download.

To enable the special feature in the software on 3000 RA and 5000 RA Processors:

a. Energize the processor if it is not already energized.
b. Change the state of the 5000 Board Dip Switch No. 2.

NOTE: The initial position of the Switch is not important. The change is what is required.

c. Enter the code "3 2 4 4" within 20 seconds.

NOTE: The Replenishment Mode Screen displays a special symbol in the upper right corner after you enable the special feature.

KODAK X-OMAT Multiloader 300:

a. On the Display Panel, select the "STD Cycle" key for standard cycle processing.

- Film is processed emulsion-side down in the Multiloader 300.
- If marks from the Guide Shoes appear on KODAK MIN-R 2000 Film, install the Smooth Guide Shoes Kit in the Developer Rack. Order the Smooth Guide Shoe Kit for the Multiloader 300, Part No. 1C7119, from Service Parts Management, 1-800-431-7278 or 716-724-7278.
- If film-sensing problems occur, install Multiloader 300 Modification No. 38.
- Upgraded Processor software may be required if processing fewer than 260 sheets 18 x 24 cm size sheets (or equivalent) per 8 hour shift, unless the Processor is operating in the flooded replenishment mode. If needed, order:

Processor	Disk* (there is no charge)	PROM Set (there is a charge)	Version Number
270 RA (integrated)	9B8537	9B8533, except Japan	3.0
		9B8535, Japan	

* Laptop required for software download of disk or install new PROM set.

No additional changes are necessary subsequent to installation of the new software.

KODAK X-OMAT 3000 RA Integrated Processor / for X-OMAT Multiloader 300 Plus or X-OMAT Multiloader 7000

The following features are included in the X-OMAT 3000 RA Integrated Processor software but are not intended for use by the customer.

The smart replenishment should be disabled as follows when processing MIN-R films only.

Warning: There will be no visible indication that the Smart Replenishment is enabled or disabled.

Feature	Purpose	Steps
Smart Replenishment Disable	Disables the Smart Replenishment Mode. Will replenish for every 238 square inches of film area only (no extra replenishment)	1. Power up the processor. 2. Change Switch 2 on the 5000 board 3. Within 5 seconds, change Switch 4 on the 5000 board. 4. Repeat the above steps to re-enable the Smart Replenishment Mode.

KODAK MIN-R Mammography Processor

- Verify transport speed for standard cycle
- Set developer temperature for standard cycle processing
- Process MIN-R 2000 Film emulsion side down due to non-uniformity issues.

KODAK Miniloader 2000P

- Using the MINILOADER 2000P with the MIN-R Mammography Processor results in film being processed emulsion side down.
- Set developer temperatures for standard cycle processing.

KODAK RP X-OMAT M6B, M6AN, and M6AW Processors:

a. Set the developer temperature and the transport speed for standard cycle processing.
b. Process KODAK MIN-R 2000 Film emulsion side up.
c. If necessary, order the following parts from Service Parts Management (1-800-431-7278 or 585-724-7278) to change an M6 Series Processor from extended to standard cycle:

For the Drive Motor	Sprocket – 20 Tooth	454454
	Setscrew	852558
For the Drive Shaft	Sprocket – 19 Tooth	458187
	2 Setscrews	852558
For the Chain	Drive Chain	469349
	Master Link	454260

KODAK RP X-OMAT M7B Processors:

a. Set the developer temperature and the transport speed for standard cycle processing.
b. Process KODAK MIN-R 2000 Film emulsion side up in a M7B Processor.
c. If necessary, order the following parts from Service Parts Management (1-800-431-7278 or 585-724-7278) to change an M7B Processor from extended to standard cycle:

For the Drive Motor	Sprocket – 19 Tooth	532247
For the Chain	Drive Chain	532248
	Master Link	188967

KODAK X-OMAT M35A-M and M35-M Processors:

a. Set the STD/EXT switch to "STD"
b. Process KODAK MIN-R 2000 Film emulsion-side down in a KODAK X-OMAT M35A-M or M35-M Processor.

NOTE: *Use of a Miniloader 2000P with a M35-M Processor results in film being processed emulsion side down. If marks from the Guide Shoes appear on MIN-R 2000 Film when processing film primary emulsion-side down, install Smooth Guide Shoes in the Developer Rack. Order the Smooth Guide Shoe Kit for the M35 Series Processors, Part No. 7C7865, from Service Parts Management (1-800-431-7278 or 585-724-7278).*

2. CHEMICALS

- Drain, clean, and refill the Developer and Fixer Tanks.
- If using an automated specific gravity based mixer and converting to KODAK X-OMAT EX II Developer and Replenisher (or KODAK RP X-OMAT Developer and Replenisher) and KODAK RP X-OMAT LO Fixer and Replenisher, ensure that the specific gravity is set as follows:

Processing Chemistry	Specific Gravity Range*
KODAK X-OMAT EX II Developer and Replenisher	1.070 to 1.080
KODAK RP X-OMAT Developer and Replenisher	1.081 to 1.091
KODAK RP X-OMAT LO Fixer and Replenisher	1.080 to 1.100

*Specific Gravity measured at 70º F.

- KODAK MIN-R 2000 Film requires 50 ml/l (6 fluid ounces per gallon) of KODAK RP X-OMAT Developer Starter. See the General Processor Information in Service Bulletin No. 30 (revised January 2004) for recommended starter volumes for a specific KODAK processor.

Optimum results are obtained using KODAK RP X-OMAT and KODAK X-OMAT EX II Developer Replenishers. Kodak does not recommend the use of KODAK Medical X-ray Developer Replenisher with KODAK MIN-R 2000 Film. The United States Food and Drug Administration (FDA) Mammography Quality Standards Act (MQSA) Final Regulations, effective April 28, 1999, states that processing solutions be capable of developing films in a manner equivalent to the minimum requirements specified by the film manufacturer. To determine if another manufacturer's developer is within Kodak's acceptable range for KODAK MIN-R 2000 Film, please refer to the *KODAK MIN-R 2000 Film System Mammography User Guide*. If attempting to use another manufacturer's developer, contact the developer manufacturer for recommended replenishment rates. If you are attempting to use another manufacturer's developer, use 6 fluid ounces per gallon of KODAK RP X-OMAT Developer Starter only.

Optimum results are obtained using KODAK RP X-OMAT LO Fixer and Replenisher.

For best results, processing solutions should be mixed with 70°F to 80°F (21.1°C to 26.6°C) water.

Warning: KODAK Medical X-ray Developer and Replenisher is not recommended for KODAK Mammography Film. KODAK Medical X-ray Fixer is not optimized for KODAK Mammography Film.

3. Adjust the Developer and Fixer Replenishment Rates.

Dedicated Processing: KODAK MIN-R 2000 Film requires specific replenishment rates for developer and fixer. See the Processing Recommendations for Dedicated Processing in Service Bulletin No. 30. These recommendations are guidelines for KODAK RP X-OMAT Developer and Replenisher, KODAK X-OMAT EX II Developer and Replenisher and KODAK RP X-OMAT LO Fixer and Replenisher. Developer and fixer replenishment rates may require adjustment for specific processing environments.

If attempting to use other manufacturer's developers and fixers, contact the manufacturer for recommended replenishment rates.

Non-Dedicated Processing: KODAK MIN-R 2000 Film can be processed with other types of medical x-ray film. Use 25 ml/l (3 fl oz per gallon) of KODAK RP X-OMAT Developer Starter for non-dedicated processing environments. KODAK MIN-R 2000 Film requires specific replenishment rates for developer and fixer. See the Processing Recommendations for Non-Dedicated Processing in Service Bulletin No. 30. These recommendations are guidelines for KODAK RP X-OMAT Developer and Replenisher, KODAK X-OMAT EX II Developer and Replenisher and KODAK RP X-OMAT LO Fixer and Replenisher. Developer and fixer replenishment rates may require adjustment for specific processing environments. If attempting to use other manufacturers' developers and fixers, contact the manufacturer for recommended replenishment rates.

Flooded Replenishment: Flooded replenishment can be used to help maintain stable processor quality control with low volume processing. For

KODAK MIN-R 2000 Film, it requires 4 ml/l (4 fl oz per gallon) of KODAK RP X-OMAT Developer Starter in the external developer replenishment tank. See the recommendations for Flooded Replenishment Rates in Service Bulletin No. 30.

When establishing replenishment rates:

- Check the settings for correct replenishment. Rates can be verified by performing an overflow test
- Check the replenishment system for kinks in the Tubing, the operation of the Recirculation and Replenishment Pumps, and the Detector Switches.
- Change any chemicals that were not mixed correctly, are exhausted, or are contaminated.

4. Dryer Temperature

Processors converted from extended to standard cycle processing may require an adjustment in the Dryer temperature to maintain adequate drying.

- Set the Dryer temperature to the minimum required to produce dry film. Tacky or wet films occurring even with adjusted Dryer temperatures may indicate that additional service is required.
- Check that the Dryer Air Tubes are in the correct positions. Remove any dirt from the Dryer Rollers and Air Tubes, especially the slots.
- Check the settings for correct replenishment.
- Check the replenishment system for kinks in the Tubing, the operation of the Recirculation and Replenishment Pumps, and the Detector Switches. Change any chemicals that were not mixed correctly, are exhausted, or are contaminated.
- Check that the Dryer air exhaust is free from any obstructions and is installed correctly according to the specifications in the installation instructions.

5. Processor Quality Control Operating Levels

The following instructions are recommendations for the control of the processor quality. Different sensitometric parameters will be monitored (MD: mid-density/speed, DD: density difference/contrast, B+F: base+fog/gross fog). You can modify these different parameters based on local regulations or guidelines.

Processor Control Aims

a. Using a Sensitometer, expose and process a Sensitometric strip. Repeat this exposure and processing once each day for five consecutive days. For large volume processing tanks or very low film volume a 10 day average may be used. For the KODAK Process Control Sensitometer, the following Dip Switch settings are recommended for KODAK MIN-R 2000 Film:

- SINGLE and GREEN settings at Exposure Setting No. 4
- 1-down, 2-down, 3-up, 4-down

For other manufacturers, follow the recommendations for optimum mammographic results (optimized green, single emulsion).

b. Read and record the densities of each step of the sensitometric strip using the densitometer, including an area of processed film that has not been exposed.

c. From the five strips, determine the average of the densities for each step using the respective densities for each step.

d. Determine which step has an average density closest to 1.20 but above 1.0. Designate this step as the mid-density (MD)/speed step. Tolerance +/- 0.10-0.15

e. Determine which step has a density closest to 2.20 and which step has a density closest to but not less than 0.45. The difference in densities between these two steps should be designated as the density difference (DD)/contrast. Tolerance +/- 0.10-0.15

f. Determine the average of the densities from the unexposed area of the five strips. This density will be designated as the base-plus-fog level (B+F)/gross fog of the film. Tolerance < 0.25

g. Start a new Processor quality control chart and record the numerical values of the MD (speed), DD (contrast) and B+F (gross fog) on the center line of the appropriate areas of the control chart.

Baseline Operating Level (on the day of conversion)

a. Using a Sensitometer, expose and process five (5) sensitometric strips at the same time and on the same side of the processor.

b. Read and record the densities of each step of the sensitometric strip using the densitometer, including an area of processed film that has not been exposed.

c. Determine the average of the densities for each step using the densities for that step from the five strips.

d. Determine which step has an average density closest to 1.20. Designate this step as the mid-density (MD)/speed step.

e. Determine which step has a density closest to 2.20 and which step has a density closest to but not less than 0.45. The difference in densities between these two steps should be designated as the density difference (DD)/contrast.

f. Determine the average of the densities from the unexposed area of the five strips. This density will be designated as the base-plus-fog level (B+F) of the film.

g. Start a new Processor quality control chart and record the numerical values of the MD (speed), DD (contrast) and B+F on the center line of the appropriate areas of the control chart.

These can be used as the baseline operating aims until the five-day averaging has been completed.

6. Automatic Exposure Control (AEC)

The desired optical density and operating kVp preference should be established. Refer to the *KODAK MIN-R 2000 Film System Mammography User Guide* (KODAK Publication # M3-108, Cat # 193 9826) for a procedure to establish kVp and optical density for MIN-R 2000 Film.

AEC/Phototimer recalibration is recommended after processing has stabilized. If this is not performed at the time of conversion, then an interim photo-timer adjustment should be determined. Using the appropriate tissue equivalent phantom, adjust the density control setting to achieve the desired optical density for the new screen/film system.

NOTE: aims in the phantom QC should be adjusted once the calibration is performed if optical density or density difference change.

The following table shows system speeds for KODAK MIN-R 2000 Film with KODAK Screens, and may be useful in determining an interim photo-timer adjustment.

Speed Contrast Comparisons for KODAK Mammography Film

Film	Screen	Processing Cycle	Relative Speed	Contrast		D-Max
				RP	EX II	
MIN-R 2000	2000	Standard	150	3.60	3.80	>4.0
MIN-R 2000	2190	Standard	190	3.60	3.80	>4.0
MIN-R 2000	MIN-R	Standard	100	3.60	3.80	>4.0
MIN-R L	2000	Standard	150	3.40	3.60	>4.0
MIN-R L	2190	Standard	190	3.40	3.60	>4.0
MIN-R L	MIN-R	Standard	100	3.40	3.60	>4.0
MIN-R M	MIN-R	Standard	100	2.95	3.15	3.9

1 Relative speed determined from matched-density radiographs of a mammography phantom. KODAK MIN-R M Film and MIN-R Screen arbitrarily assigned a relative speed of 100.

Appendix

Table of Contents

1 Conversion and Processing Recommendations for KODAK MIN-R EV Film 120

2 Technical Bulletin 3111 (sources: Service Bulletin No. 101 and 180)..... 137

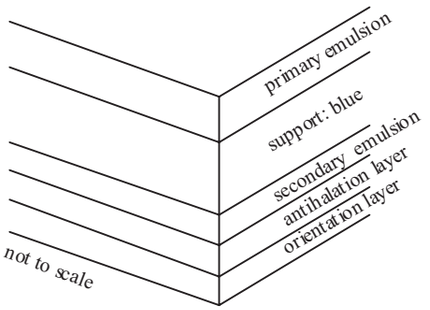
3 Ventilation 140

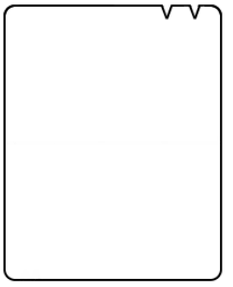
4 MQSA Equivalency Statement 142

Conversion Instructions and Processing Recommendations

For KODAK MIN-R EV Mammography Film

- MIN-R EV has a novel double emulsion design, for use with standard, green-emitting single screen cassettes.
- MIN-R EV is identified by a spaced double V-notch. The primary emulsion is up when the notch is on the right hand side at the top edge of the film. The primary emulsion must be in contact with the screen during imaging.
- Kodak has added an orientation layer to the film to aid in the identification of the primary emulsion side; the dull side identifies the primary emulsion side of the film (the side which is to be placed against the screen during imaging).
- KODAK MIN-R EV Film is designed for optimal results in standard cycle processing
  - The film may be processed in Rapid cycle when used with KODAK X-OMAT EX II or KODAK RP X-OMAT Developer and KODAK RP X-OMAT LO Fixer.
- In documentation that refers to the emulsion side of the film, this should be considered a reference to the primary emulsion of MIN-R EV film.





Not to scale

OBJECTIVES OF THE CONVERSION GUIDE

- Establish/verify correct processing parameters for KODAK MIN-R EV Film
- Establish quality control aims
- Establish initial image quality parameters
- Verify other Quality Control tests

Tools Required:

- Sensitometer capable of producing 21 steps
- Densitometer capable of spot reading greater than optical density of 4.5
- Thermometer
- Curve plotting paper (KODAK Publication # M3-58, Cat # 841 2843) or scanning densitometer
- 4-5 cm Lucite or BR 12 tissue equivalent phantom (RMI 156, Nuclear Associates 18-220)

Reference Material:

- *KODAK MIN-R Mammography Screen/Film Systems User Guide* (KODAK Publication #M3-103, Cat # 173 9473)
- Service Bulletin No. 30, revised January 2004
- *Mammography Quality Control Manual* 1999, American College of Radiology

Before you begin

Benchmark the facility using the mammography benchmarking form.

- Compare sensitometry (current film versus MIN-R EV)
- Compare accreditation phantom (current film versus MIN-R EV)
- Perform the optical density and kVp series with MIN-R EV

Processors

KODAK MIN-R EV Film is designed for optimal results in standard cycle processing. All KODAK X-OMAT Processors should be adjusted to comply with the standard cycle processing parameters listed in the film processing instructions for that specific processor. If using KODAK X-OMAT EX II or KODAK RP X-OMAT Developer and KODAK RP X-OMAT LO Fixer, the film may be processed in the Rapid cycle. If using the rapid cycle, all KODAK X-OMAT Processors should be adjusted to comply with the rapid cycle processing parameters listed in the film processing instructions for that specific processor.

KODAK MIN-R EV Film should be processed primary emulsion side down in the KODAK MIN-R Mammography and KODAK X-OMAT M35A-M / M35-M processors. Best results will be obtained using the KODAK MIN-R Mammography processor.

Processor	Process MIN-R EV Primary Emulsion Up/Down
MIN-R Mammography, M35A-M, M35M	Down
3000 RA, 270 RA, M7 series	Up
M6 B, M6R, 5000 RA, 480 RA, 460 RA	Up

NOTE: *The KODAK Medical X-Ray, X-OMAT M43, M43A, Clinic 1, X-OMAT 1000, M35A, M35 and X-OMAT 2000 and 2000 A Processors are not recommended for processing KODAK MIN-R EV Film (or other KODAK Mammography Films). Other manufacturers' processors with shallow developer tanks or short developer racks may not produce optimum results if used to process KODAK MIN-R EV Film. Consult the processor manufacturer recommendations for standard/rapid cycle processing set-up.*

Chemicals

- Drain, clean, and refill the Developer and Fixer Tanks.
- If using an automated specific gravity based mixer and converting to KODAK X-OMAT EX II Developer and Replenisher (or KODAK RP X-OMAT Developer and Replenisher) and KODAK RP X-OMAT LO Fixer and Replenisher, ensure that the specific gravity is set as follows:

Processing Chemistry	Specific Gravity Range*
KODAK X-OMAT EX II Developer and Replenisher	1.070 to 1.080
KODAK RP X-OMAT Developer and Replenisher	1.081 to 1.091
KODAK RP X-OMAT LO Fixer and Replenisher	1.080 to 1.100

*Specific Gravity measured at 77°F.

- KODAK MIN-R EV Film requires 25 ml/l (3 fluid ounces per gallon) of KODAK RP X-OMAT Developer Starter. See the attached General Processor Information for recommended starter volumes for a specific KODAK processor.

Optimum results are obtained using KODAK X-OMAT EX II and RP X-OMAT Developer Replenishers. Kodak does not recommend the use of KODAK Medical X-ray Developer Replenisher with KODAK MIN-R EV Film. The United States Food and Drug Administration (FDA) Mammography Quality Standards Act (MQSA) Final Regulations, effective April 28, 1999, states that processing solutions be capable of developing films in a manner equivalent to the minimum requirements specified by the film manufacturer. To determine if another manufacturer's developer is within Kodak's acceptable range for KODAK MIN-R EV Film, please refer to the KODAK MIN-R EV Film System Mammography User Guide. If attempting to use another manufacturer's developer, contact the developer manufacturer for recommended replenishment rates.

Optimum results are obtained using KODAK RP X-OMAT LO Fixer and Replenisher. For best results, processing solutions should be mixed with 70°F to 80°F (21.1°C to 26.6°C) water.

Warning: KODAK Medical X-ray Developer and Replenisher is not recommended for KODAK Mammography Film. KODAK Medical X-ray Fixer is not optimized for KODAK Mammography Film.

Adjust the Developer and Fixer Replenishment Rates

Dedicated Processing: KODAK MIN-R EV Film requires specific replenishment rates for developer and fixer. These recommendations are guidelines for KODAK X-OMAT EX II Developer and Replenisher,

KODAK RP X-OMAT Developer and Replenisher and KODAK RP X-OMAT LO Fixer and Replenisher. Developer and fixer replenishment rates may require adjustment for specific processing environments.

If attempting to use other manufacturer's developers and fixers, contact the manufacturer for recommended replenishment rates.

Recommended Replenishment Rates

Dedicated Mammography

A processor is considered dedicated if only mammography or single-emulsion film such as ltrasound is processed.

General purpose (non-dedicated) processors should use the replenishment rates listed for general radiography.

***NOTE:** These guidelines should be used as initial starting points only. If adjustments are made from these it is recommended that only 10% change be made at any one time.*

For Area Processors with Smart Replenishment

- KODAK X-OMAT Processor Models 270 RA, 3000 RA, M6RA, 460 RA, 480 RA, 5000 RA
- KODAK X-OMAT Multiloader 7000, KODAK X-OMAT Multiloader 300/300 Plus
  - Smart Replenishment is enabled by default. It is recommended that smart replenishment be disabled for MIN-R EV film. Consult service.
  - The equivalent area of a 35 x 43 cm (14 x 17 in.) film is 1505 cm sq. (238 sq. in.).
  - Replenishment takes place after the equivalent area of a 35 x 43 cm (14 x 17 in.) film has been fed; therefore, replenishment rates must be set for a 35 x 43 cm (14 x 17 in.) film feed.
  - Additional replenishment occurs automatically during low film usage. This feature can be overridden by using software version 3.0 or higher. Note: X-OMAT 3000 RA and X-OMAT 5000 RA Processors have the ability to override this feature without installing new software.

Film Processed	Use Condition	Average Number of Films per 8 hrs Of Processor Operation	Replenishment Rates* (ml per 35 x 43 cm)	
			Developer	Fixer
MIN-R EV	Smart Replenishment disabled (recommended)	60 sheets or more	90	105
		Less than 60 sheets	Flooded	Flooded
MIN-R EV	Smart Replenishment enabled	260 sheets or more	90	105
		200 sheets	80	
		150 sheets	70	
		100 sheets	65	
		70 sheets	60	
		Less than 60 sheets	Flooded	Flooded
* Flooded replenishment is available if needed to maintain sensitometry for very low use conditions.				

Smart replenishment should be turned off (refer to Service Bulletin No. 30)

For Length Processors

- KODAK X-OMAT Processor Models M35-M, M35A-M, M7B, M7B-E, M6A-N, M6AW, M6B, M6R
- KODAK MIN-R Mammography Processor
  - Replenishment takes place whenever film is in the entrance rollers.
  - Replenishment rates must be set according to usage and film size(s) fed.
  - MIN-R EV Film is fed primary emulsion side down in M35-M, M35A-M, and MIN-R Mammography Processors.
  - For the KODAK Multiloader 700 docked to length replenished processors, mammography rates are set using 18 cm film travel.

Film Processed	Film Feeding	Use Condition	Average Number of Films per 8 hrs Of Processor Operation	Replenishment Rates (ml per 18 x 24 cm)**	
				Developer	Fixer
MIN-R EV	Single	Medium - High Low	60 sheets or more 60 sheets or less*	25 Flooded	30 Flooded
	Double	Medium - High Low	60 sheets or more 60 sheets or less*	50 Flooded	60 Flooded
* If flooded replenishment is not used, sensitometry may not stay within control limits. ** Use a single 18 x 24 cm film to set the replenishment rates listed.					

Recommended Replenishment Rates

Non-Dedicated Mammography

Non-Dedicated Processing: KODAK MIN-R EV Film can be processed with most current traditional medical x-ray film. Kodak does not recommend processing Helium Neon and IR films with KODAK MIN-R EV Film. Use 25 ml/l (3 fl oz per gallon) of KODAK RP X-OMAT Developer Starter for non-dedicated processing environments. KODAK MIN-R EV Film requires specific replenishment rates for developer and fixer. These recommendations are guidelines for KODAK X-OMAT EX II Developer and Replenisher, KODAK RP X-OMAT Developer and Replenisher, and KODAK RP X-OMAT LO Fixer and Replenisher. Developer and fixer replenishment rates may require adjustment for specific processing environments. If attempting to use other manufacturers' developers and fixers, contact the manufacturer for recommended replenishment rates.

For Area Processors with Smart Replenishment

- KODAK X-OMAT Processor Models 270 RA, 3000 RA, M6RA, 460 RA, 480 RA, 5000 RA
- KODAK X-OMAT Multiloader 7000, KODAK X-OMAT Multiloader 300/300 Plus
  - Smart Replenishment is enabled by default.
  - Replenishment takes place after the equivalent area of a 35 x 43 cm (14 x 17 in.) film has been fed; therefore, replenishment rates must be set for a 35 x 43 cm (14 x 17 in.) film feed.
  - Additional replenishment occurs automatically during low film usage.

Film Size Processed	Use Condition	Average Amount of 35 x 43 cm Equivalent Films per 8 hrs of Processor Operation	Replenishment Rates (ml per 35 x 43 cm)	
			Developer	Fixer
All	Any	Any number*	60	85
* Flooded replenishment should not be needed due to the automatic compensation for use, but it is available if needed to maintain sensitometry for very low use conditions (fewer than the equivalent of 25 35x43 cm films).				

For Length Processors

- KODAK X-OMAT Processor Models M35-M, M35A-M, M7B, M7B-E, M6A-N, M6AW, M6B, M6R
- KODAK MIN-R Mammography Processor
  - Replenishment takes place whenever film is in the entrance rollers.
  - Replenishment rates must be set according to usage and film size(s) fed.
  - Film should be fed as recommended in the processor Operator Manual/User Guide.

Processor	Process MIN-R EV Primary Emulsion Up/Down
MIN-R Mammography, M35A-M, M35M	Down
3000 RA, 270 RA, M7 series	Up
M6 B, M6R, 5000 RA, 480 RA, 460 RA	Up

- X-OMAT M35M, M35A-M and MIN-R Mammography Processors are not recommended for roll film

Film Size Processed	Use Condition	Average Number of Films per 8 hrs Of Processor Operation	Replenishment Rates (ml per 35 x 43 cm)	
			Developer	Fixer
Average size intermix	High Medium Low	115 sheets or more 40 - 115 sheets 40 sheets or less*	50 65 80	70 85 100
* If flooded replenishment is not used, sensitometry may not stay within control limits.				

Flooded Replenishment: Flooded replenishment can be used to help maintain stable processor quality control with low volume processing. For KODAK MIN-R EV Film, **it requires 25 ml/l (3 fl oz per gallon) of KODAK RP X-OMAT Developer Starter in the external developer replenishment tank.**

Flooded Replenishment Rate Recommendations

- For low use rates, if sensitometry does not stay within control limits, flooded replenishment may be needed to maintain the developer solution at a continuously fresh chemical activity. This is accomplished by replenishing not only when film is fed or area accumulated, but also on the basis of additional replenishment added during the processor on time with an automatic replenishment timing system.
- When in the flooded mode, developer starter is added to the replenishment tanks at a rate of 89 ml per gallon or 25 ml per liter (3 fl oz per gallon) for MIN-R EV film.
- For detailed information on how to set up each processor for flooded replenishment, see the appropriate service publication for that processor.
- Qualified service personnel should do the processor setup.
- When filling the developer replenishment or processor tank, add starter according to the table below.

KODAK Developer	Flooded Mode	Add Starter?	
		Replenishment Tank	Processor Tank
X-OMAT EX II	No Yes	No Yes	Yes No*
RP X-OMAT	No Yes	No Yes	Yes No*
* Fill the processor tank with chemistry that was mixed in the replenishment tank.			

Dryer

Dedicated processors converted to MIN-R EV film may be able to reduce the dryer temperature. An uneven density pattern may be noted if the dryer temperature is too high. Please refer to Section 7.

- Set the Dryer temperature to the minimum required to produce dry film. Tacky or wet films occurring even with adjusted Dryer temperatures may indicate that additional service is required.
- Check that the Dryer Air Tubes are in the correct positions. Remove any dirt from the Dryer Rollers and Air Tubes, especially the slots.
- Check the settings for correct replenishment.
- Check the replenishment system for kinks in the Tubing, the operation of the Recirculation and Replenishment Pumps, and the Detector Switches. Change any chemicals that were not mixed correctly, are exhausted, or are contaminated.
- Check that the Dryer air exhaust is free from any obstructions and is installed correctly according to the specifications in the installation instructions.
- You may be able to decrease the dryer temperature.
- Should uneven density be noticed, refer to Section 7, evaluating the Imaging Chain for Uniformity.

General Processor Information

NC = Not Controlled (temperature)

NR = Process Not Recommended for this film type

Processor Model	Cycle	Approx Devl Tank Volume	Starter Volume	Temperature			Transport Speed	Capacity 35 x 43 cm (18 x 24 cm)	Approx Devl Time	Approx Drop Time** 35cm length (24cm length)
			MIN-R EV	Dev	Fixer*	Water				
		gal (L)	fl oz (ml)	°F (°C)	°F (°C)	°F (°C)	in./min (cm/min)	films/hr	seconds	seconds
M35-M M35A-M	S	2.25 (8.3)	6.5 (190)	92°F (33.3°C)	NC	40° - 85°F (4° - 29.4°C)	30 (76.2)	94 (145)	33	150 (135)
MIN-R Mammo	S	2.25 (8.3)	6.5 (190)	92°F (33.3°C)	NC	40° - 85°F (4° - 29.4°C)	30 (76.2)	(145)	33	150 (135)
	R			94°F (34.4°C)					25	112 (101)
M7B M7B-E	S	2.25 (8.3)	6.5 (190)	94°F (34.4°C)	NC	40° - 85°F (4° - 29.4°C)	42 (106.7)	146 (250)	27	120 (116)
3000 RA 270 RA XML300 XML300+ XML7000	S	2.25 (8.3)	6.5 (190)	94°F (34.4°C)	90°F (32°C)	40° - 85°F (4° - 29.4°C)	42 (106.7)	148 (250)	26	111 (104)
	R			99°F 37.2°C	95°F (35°C)		57 (144.8)	201	19	82
M6A-N M6AW M6B M6R	S	2.8 (10.7)	Molded: 8.5 (250) Stain-less: 8 (237)	95°F (35°C)	NC	M6A-N: 85° - 90°F (30°-32.2°C) M6AW, M6B: 40° - 90°F (4° - 32.2°C)	66 (167.6)	229 (393)	25	90 (86)
M6RA 460 RA 480 RA 5000 RA	S	2.8 (10.7)	8.5 (250)	95°F (35°C)	95°F (35°C)	40° - 85°F (4° - 29.4°C)	66 (167.6)	233 (393)	24	95 (89)
	R			101°F (38.3°C)			99 (251.5)	351	16	60

* Fixer temperature may exceed value listed due to internal ambient temperatures in the processor.

** Drop Time is defined as the time from the Lead Edge In (LEI) to the Trail Edge Out (TEO) for a 35 x 43 cm film. (Represents 18 x 24 cm LEI/TEO)

Processor Quality Control Operating Levels

The following instructions are recommendations for the control of the processor quality. Different sensitometric parameters will be monitored (MD: mid-density/speed, DD: density difference/contrast, B+F: base+fog/gross fog). You can modify these different parameters based on local regulations or guidelines.

Processor Control Aims

a. Using a Sensitometer, expose and process a Sensitometric strip. Repeat this exposure and processing once each day for **five consecutive days**. For large volume processing tanks or very low film volume a 10 day average may be used. For the KODAK Process Control Sensitometer and X-rite models 394 and 396, the following Dip Switch settings are recommended for KODAK MIN-R EV Film:

   - SINGLE and GREEN settings at Exposure Setting No. 4
   - 1-down, 2-down, 3-up, 4-down
     – Using a lower exposure setting will decrease the optical density, using a higher exposure setting will increase the optical density.

   For other manufacturers, follow the recommendations for optimum mammographic results (optimized green, single emulsion).

b. Read and record the densities of each step of the sensitometric strip using the densitometer, including an area of processed film that has not been exposed.

c. From the five strips, determine the average of the densities for each step using the respective densities for each step.

d. Determine which step has an average density closest to 1.20 but above 1.0. Designate this step as the mid-density (MD)/speed step. Tolerance +/- 0.10-0.15

e. Determine which step has a density closest to 2.20 and which step has a density closest to but not less than 0.45. The difference in densities between these two steps should be designated as the density difference (DD)/contrast. Tolerance +/- 0.10-0.15

f. Determine the average of the densities from the unexposed area of the five strips. This density will be designated as the base-plus-fog level (B+F)/gross fog of the film. Tolerance < 0.25

g. Start a new Processor quality control chart and record the numerical values of the MD (speed), DD (contrast) and B+F (gross fog) on the centerline of the appropriate areas of the control chart.

Baseline Operating Level
(on the day of conversion)

a. Using a Sensitometer, expose and process five (5) sensitometric strips at the same time and on the same side of the processor.

b. Read and record the densities of each step of the sensitometric strip using the densitometer, including an area of processed film that has not been exposed.

c. Determine the average of the densities for each step using the densities for that step from the five strips.

d. Determine which step has an average density closest to 1.20. Designate this step as the mid-density (MD)/speed step.

e. Determine which step has a density closest to 2.20 and which step has a density closest to but not less than 0.45. The difference in densities between these two steps should be designated as the density difference (DD)/contrast.

f. Determine the average of the densities from the unexposed area of the five strips. This density will be designated as the base-plus-fog level (B+F) of the film.

g. Start a new Processor quality control chart and record the numerical values of the MD (speed), DD (contrast) and B+F on the centerline of the appropriate areas of the control chart.

   These can be used as the baseline operating aims until the five-day averaging has been completed.

Automatic Exposure Control (AEC)

The desired optical density and operating kVp preference should be established. Please refer to the *KODAK MIN-R Mammography Screen/Film Systems User Guide*, M3-103, CAT No. 173 9473 for a procedure to establish kVp and optical density for MIN-R EV Film.

Auto AEC/Phototimer recalibration is recommended after processing has stabilized. Customers should consult their x-ray equipment manufacturer to ensure proper recalibration. If this is not performed at the time of conversion, then an interim AEC photo-timer adjustment should be determined. Using the appropriate tissue equivalent phantom, adjust the density control setting to achieve the desired optical density for the new screen/film system. **Due to the significant difference in the curve shape of MIN-R EV film, optimum results for all breast types may not be achieved if the mammography x-ray unit is NOT calibrated for MIN-R EV.**

NOTE: *aims of the phantom QC should be adjusted once the calibration is performed if optical density or density difference change.*

The following table shows system speeds for KODAK MIN-R EV Film with KODAK MIN-R EV Screens, and may be useful in determining an interim AEC adjustment.

Speed Contrast Comparisons for KODAK Mammography Film

Film	Screen	Processing Cycle	Relative Speed	Contrast		D-Max
				RP	EX II	
MIN-R EV	MIN-R EV 150	Standard/ Rapid	150	4.5	4.7	>4.5
MIN-R EV	MIN-R EV 190	Standard/ Rapid	190	4.5	4.7	>4.5
MIN-R 2000	MIN-R 2000	Standard	150	3.60	3.80	>4.0
MIN-R 2000	MIN-R 2190	Standard	190	3.60	3.80	>4.0
MIN-R 2000	MIN-R	Standard	100	3.60	3.80	>4.0
MIN-R L	MIN-R 2000	Standard	150	3.40	3.60	>4.0
MIN-R L	MIN-R 2190	Standard	190	3.40	3.60	>4.0
MIN-R L	MIN-R	Standard	100	3.40	3.60	>4.0

1 Relative speed determined from matched-density radiographs of a mammography phantom. KODAK MIN-R M Film and MIN-R Screen arbitrarily assigned a relative speed of 100.

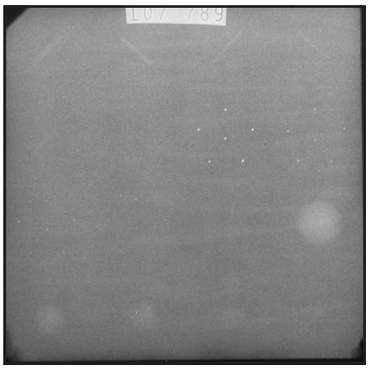
2 Contrast was measured as the average gradient between densities 0.25 and 2.00 above gross fog using inverse square sensitometry.

While system speeds may be similar, screen absorptions are different. Equipment adjustment will be necessary.

Evaluating the Imaging Chain for Uniformity

Description:

- Pattern of plus or minus density
- May appear either as a band or a diffuse region
- Readily seen on a flat field or phantom, rarely in the clinical image
- Can appear across the image, but seen most often in a uniform phantom along the chest wall side of the image



Probable Cause or Causes:

The density pattern may be caused by a combination of factors in the exposing and processing of the film.

- Grid/cassette holder
  - Grid motor
  - Grid artifact/defect
  - Carbon fiber top damage
- Dryer
  - Dryer temperature too high
  - Air tubes blocked or obstructed
  - Buildup on dryer rollers
  - Squeegee rollers
  - Dryer venting
- Processor
  - Hesitation in developer rack
  - Stubbing in developer rack
  - Processor type
    - Some processors have a better path through the developer, wash and dryer (e.g. MIN-R Mammography or X-OMAT 5000 RA processor)
    - Note: In deep tank processors, test films should be processed emulsion up and down to determine best orientation for uniformity.
    - Films must be processed emulsion down in X-OMAT M35M, M35A-M and MIN-R Mammography processors.

- Chemistry
  - Type and/or quality of the chemistry
    - Mixed and replenished properly

    NOTE: *High contrast developers may increase the visualization of breast structure. Consequently, they may also enhance the visualization of any anomalies present in the imaging chain. The visualization of grid and dryer patterns may be more pronounced with these developers.*

Isolating Non-Uniformity

Step 1. Determine if the artifact is coming from the processor or the X-ray exposure equipment

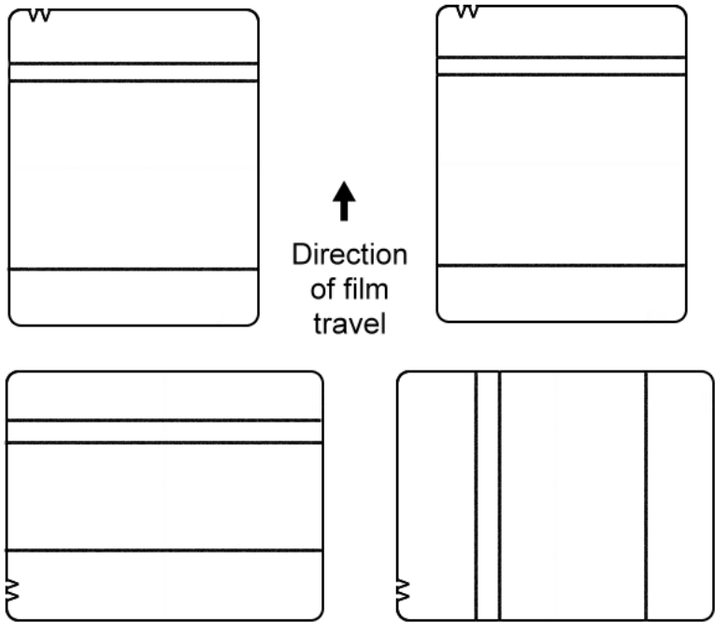
Equipment Needed

- 1 inch (2cm) thick uniform sheet of acrylic or Lucite
- Cassette with known good screen-film contact

The following procedure may be used to make this evaluation:

- Expose films to an optical density of 1.10 to 1.50, using the same cassette and the uniform sheet of acrylic.
  - The exposure time used should be at least 0.5 seconds or longer to eliminate grid artifacts caused by too short an exposure time.
  - The cassette must be known to have good screen-film contact.
- Process one film so that the narrowest dimension of the film is the leading edge; process a second film so that the widest dimension of the film is the leading edge.
- Once processed, view the film pairs (or single films) in the same orientation as processed.
- Artifacts that are parallel to each other on a film pair occurred in the processor (artifacts may be parallel or perpendicular to film travel).

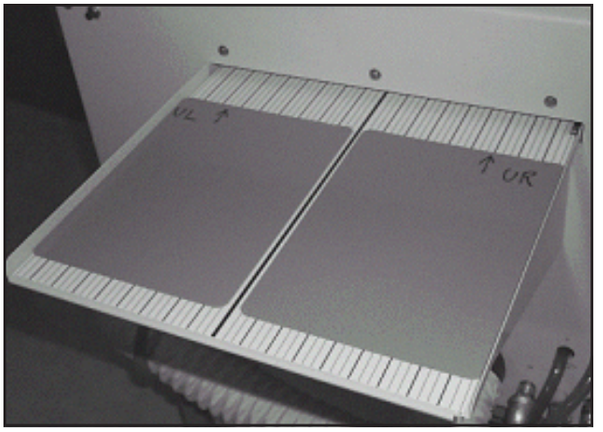
Artifacts that are perpendicular to each other on a film pair occurred during exposure from the x-ray unit.



All films processed emulsion down, on the right side of feed tray.

Artifacts that are parallel to each other are caused by the processor; artifacts that are perpendicular are caused during exposure.

If the artifact is processor caused:



- Lay the film on the film feed tray in the darkroom, and mark an arrow (↑) on the corner of the film with a lead pencil immediately before processing to indicate the direction of film travel.
- It is also helpful to mark the emulsion orientation (up [U] or down [D]), as well as which side of the processor feed tray (right [R] or left [L]) is being used, when feeding the film into the processor, e.g., ↑UR (emulsion up, right side feed tray)

Note that processors in which MIN-R EV Mammography film will be processed should be evaluated initially to determine whether films should be processed emulsion side up or emulsion side down—which orientation provides the best uniformity and the fewest artifacts—before processing clinical and quality control films.

- To thoroughly evaluate the entire processor, up to ten films should be exposed and processed as described above: one pair emulsion side up on the right side of the film feed tray, one pair emulsion up on the left side of the feed tray, one pair emulsion side down on the right side of the film feed tray, and one pair emulsion side down on the left side of the film feed tray.
- Expose the first two film pairs that will be processed as described above (emulsion side up on right, emulsion side up on left) using the small moving grid device (18 x 24 cm bucky) and use to evaluate whether artifacts are being generated by the x-ray unit in conjunction with the small bucky.
- Careful analysis of all of the films will indicate whether emulsion side up or down gives the best overall processing results.
  - the protocol should subsequently be posted in the darkroom so all films are processed consistently
    - All clinical images, sensitometric strips, and phantom images emulsion side up or all emulsion side down.
    - Determine which side of the processor and which orientation (emulsion up or down) gives the best uniformity.

Film must be processed emulsion side down in the MIN-R Mammography, X-OMAT M-35AM, and X-OMAT M-35M Processors. (Multiloaders may be excluded as film orientation during processing is fixed.)

- Quality control films (phantom images and sensitometric strips) should also be processed in a specific location with respect to the film feed tray (right side or left side, with the edge of the film butted against the guide of the film feed tray).

Determine how much of the non-uniformity pattern is coming from the grid. Changes made to the processor will not be able to improve upon this.

- Expose with and without the grid.
  - Expose one film as normal and process emulsion side down on the non-gear side of the processor.
  - Make a table top exposure (set the loaded cassette on top of the table, place the Lucite on top and make the exposure) and process emulsion side down on the non-gear side of the processor.

Please contact the equipment manufacturer if the pattern is noticeable.

With grid—note non-uniform pattern

Without grid

Please record your results in Section 1 of the Troubleshooting Non-Uniformity worksheet.

Step 2. Test the ventilation of the processor by following the procedure outlined below

Failure to properly vent the processor or multiloader exhaust can cause corrosion inside the equipment (and any interfaced equipment) and can increase the probability of film artifacts. Venting according to the specifications outlined in this bulletin will help minimize these problems.

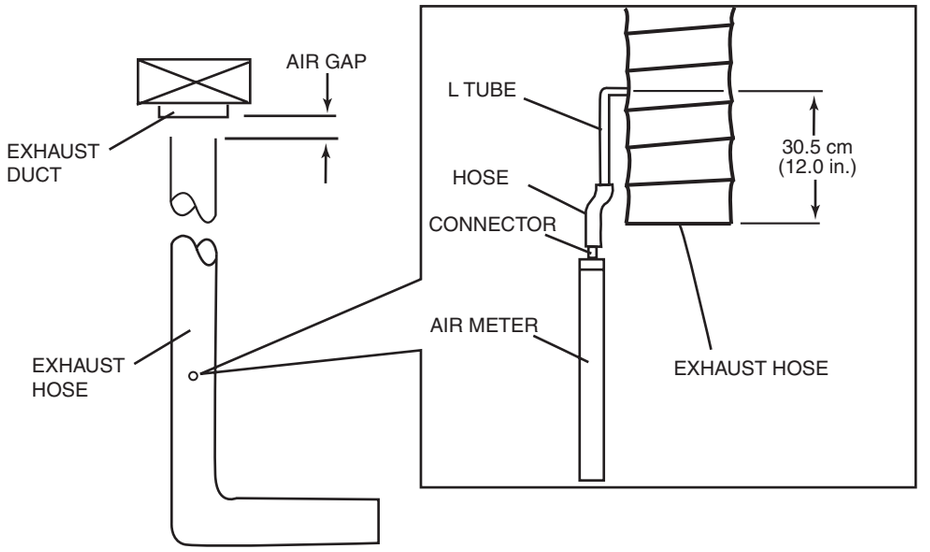
Some equipment (like the KODAK X-OMAT 5000 RA Processor) may have different procedures and specifications for exhaust measurement. Service documentation for a particular piece of equipment always takes precedence over these recommendations.

Items Needed

1. Air Meter (TL-2431).

   The above item can be ordered through Service Parts Management at 800-431-7278 (U.S.) or 585-724-6075 (Outside U.S.).

STEP	ACTION
1	Make sure the processor/multiloader exhaust hose is connected to the building exhaust system. Disposal of effluent air must comply with prevailing environmental codes.
2	*Power down the processor/multiloader.*
3	Disconnect the exhaust hose from the rear of the equipment.
4	Connect the rubber hose on the Air Meter's **center** connector.
5	Connect the L Tube to the rubber hose.
6	Make a 6.4 mm (1/4 in.) hole approximately 30.5 cm (12 in.) from the end of the exhaust hose that will be connected to the processor.
7	Insert the L Tube into the hole (Step 6) so the end of the L Tube is flush with the inside of the exhaust hose and perpendicular to the wall of the exhaust hose.
Important: Do not connect the exhaust hose to the processor when checking negative static pressure.	



Procedure: Measuring the Static Pressure

Step	Action
1	Hold the air meter vertically to assure the greatest accuracy. Make sure the meter tubing is not kinked.
2	Record the average of several readings.
3	Compare the average reading with the information in the table below (Measuring the Static Pressure). **Important:** The negative airflow in the processor exhaust duct must remain constant when the processor is in the run, standby, and shut-down mode; therefore, the building exhaust system must be on 24 hours a day and have the same negative airflow throughout the day.
4	If the average reading is not within the tolerances specified in the table, adjust the Air Gap Assembly to obtain the tolerances. If the tolerances still cannot be obtained and you must exceed the maximum in order to obtain the correct negative static pressure, contact site management personnel to have the building exhaust corrected. **Important:** There must be an adequate air gap (maximum 5.08 cm / 2 inches) between the processor exhaust hose and the building exhaust to prevent positive airflow from flowing back into the processor. If the building exhaust venting system cannot meet specifications, an Auxiliary Ventilation Fan Kit can be ordered through Service Parts Management.
5	Reconnect the exhaust hose to the processor.

Measuring the Static Pressure

Duct Diameter	Negative Static Pressure of Water Head	
	Minimum	Maximum
76 mm (3 in)	0.76 mm (0.03 in.)	1.02 mm (0.04 in.)
102 mm (4 in.)	0.25 mm (0.01 in.)	0.51 mm (0.02 in.)

Additional Notes

If the processor/multiloader is installed in a darkroom wall opening, the darkroom air pressure *must exceed the air pressure of the area outside the darkroom.* This will:

- Prevent air from cascading through the processor and into the darkroom area.
- Assure correct dryer venting.
- Minimize chemical fume and vapor containment inside the processor and its dryer exhausting system.
- Reduce film artifacts in the out-of-solution transport roller sections.
- Reduce corrosion of the processor/multiloader.

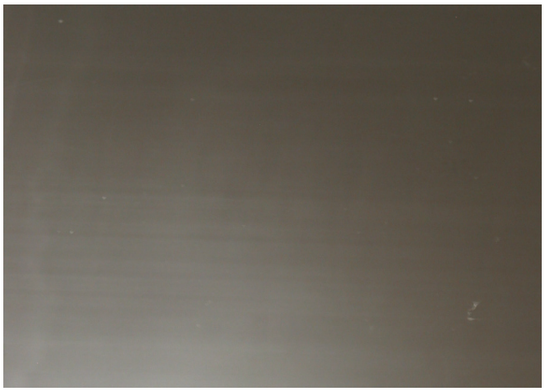
Room Ventilation

The room must have a minimum of 10 air exchanges each hour.

Record your results in Section 2 of the Troubleshooting Non-Uniformity worksheet.

Step 3. Having ruled out the x-ray unit and grid and the ventilation as causes of the uneven density, look at the films by reflected light to see if the uneven density pattern is visible.

To rule out the dryer as a cause, expose several additional flat field films, following the procedure above. Process the first film in the orientation that gave you the best results in step 1 and catch it as it exits the wash rack prior to entering the dryer section. Let it air dry.



The dryer pattern exhibited on the left is visible by both reflected and transmitted light. It may be minimized by following the recommendations on page 134 of this document.

Examine the film to see if the non-uniformity changes. If it does, then follow the corrective actions for dryer pattern. Record your results in Section 3 of the Troubleshooting Non-Uniformity Worksheet.

Step 4. If the uneven density pattern does not change in step 3, try to isolate which rack in the processor it may be occurring.

Record your results in Section 4 of the Troubleshooting Non-Uniformity worksheet.

Corrective Action (according to cause):

Symptom	Cause	Corrective Action
Grid non-uniformity		Contact your x-ray equipment manufacturer.
Shoreline Artifacts (visible in both transmitted and reflected light)	Dryer Temperature too high	Turn down dryer temperature as low as possible to dry the film.
	Air tubes blocked or obstructed	Clean air tubes (Check at each PM or as needed). Try rotating several air tubes by 180 degrees
	Wash rack squeegee rollers	Squeegee rollers must be clean and in good working order. (Check imperfections, spring pressure, smooth rotation, etc.)
	Poor ventilation	Check the ventilation as per procedure in Service Bulletin No. 101.
	Improperly mixed, under-replenished developer and fixer	Review mixing procedures. Verify that the replenishment rates are set appropriately (as per Service Bulletin No. 30 recommendations).
Hesitation Marks/stub lines (visible in transmitted light)	Change in velocity of the film travel resulting from interference within the film path	
	Malfunctioning rack or drive component (roller, gear, chain, drive motor or sprocket)	Repair or replace rollers, bearings, shafts, sideplates, gears, gudgeons and guide shoes
	Incorrectly assembled or damaged guide shoes	Check that the guide shoes are not loose and are positioned in the correct direction
	Guide Shoes out of adjustment or out of alignment	Check that the developer rack and developer/fixer crossover are assembled correctly
	Chemical buildup on rollers	Inspect all rollers for dirt and buildup of dried chemicals. Clean the rollers according to manufacturer's recommendations.
	Warped or rough rollers	
	Worn roller bearings, shafts and sideplates	Check that the sideplates of the guide shoes are correctly oriented
	Idler rollers not turning	Adjust rack chains
	Damaged gear or gudgeon	
	Improperly mixed or depleted developer and/or fixer	Review mixing procedures. Verify that the replenishment rates are set as per Service Bulletin No. 30 recommendations.

As per the guidance on page 255 of the ACR's **Mammography Quality Control Manual 1999** "If **significant** film processor artifacts are detected, contact the person maintaining the processor or the film processor service organization or dealer. Contact the X-ray equipment service person for suggestions on additional testing procedures and for help in correcting X-ray equipment artifacts. Gentle cleaning may be able to eliminate cassette or screen artifacts. Not all artifacts can be totally eliminated. It may be helpful to use the concept of ALARA (as low as reasonably achievable) when attacking artifacts. If they can be easily eliminated, they should. If the artifact is difficult or expensive to eliminate and is subtle (not mimicking or obscuring clinical information), it may be tolerable. The medical physicist should consult with the interpreting physician as to whether the artifact is tolerable."

Troubleshooting Non-Uniformity Worksheet

Section 1). Determine if the artifact is coming from the processor or the X-ray exposure equipment

After completing the tests on pages 129-130, please compare the test films and record your results below:

Grid versus non bucky comparison:__
_____

Emulsion Up versus Emulsion Down comparison:_____
_____

Non-gear versus gear side of processor:
_____
_____

Section 2). Determine the ventilation of the processor

Record your results and compare to Kodak's recommendations on page 132:

Negative static pressure:_____

Results within Kodak's recommendations? Y N

Section 3) Ruling out the dryer as a cause of the uneven density pattern

Perform the test as outlined on page 133.

Examine the resulting films to see if the uneven density pattern changes.

Record your results:

Did the dryer pattern change? Y N

If it does, then follow the corrective action for dryer pattern on page.

Section 4) If the uneven density pattern does not change, try to isolate which rack in the processor in which it may be occurring.

Results:

Pattern was isolated in the:
developer rack fixer rack wash rack

Could not isolate pattern.

If you cannot isolate the cause of the pattern, please send a copy of this form, your test films and the completed Information Needed by Kodak to Facilitate Troubleshooting form to:

Eastman Kodak Company
Health Imaging Technical Support
343 State Street
Rochester, NY 14650-1131

Other Mammography Quality Control Tests

- Emulsion Log

  KODAK MIN-R Mammography Screen/Film Systems User Guide, (KODAK Publication # M3-103, CAT No. 173 9473).

  – *Phantom Image Evaluation*
  Perform the test as described in the Mammography Quality Control Manual for Radiologists, Medical Physicists, and Technologists, American College of Radiology 1999 (ACR QC Manual) page 258.
    - Note any changes in the number of test objects seen. Re-establish the baseline numbers.
    - The density difference on the phantom may be significantly higher due to the high contrast of KODAK MIN-R EV Film.

  – *Darkroom Fog Test*
  Perform the test as described in the *KODAK MIN-R Mammography Screen/Film Systems User Guide*, (KODAK Publication # M3-103, CAT No. 173 9473). Please note that a 7.5 watt bulb is recommended with KODAK mammography film.

  – *Analysis of Fixer Retention in Film*
  Perform the test as described in the *KODAK MIN-R Mammography Screen/Film Systems User Guide*, (KODAK Publication # M3-103, CAT No. 173 9473).

The conversion to MIN-R EV Film includes a conversion to new KODAK MIN-R EV Screens. The following tests should be performed:

- *Screen-Film Contact*
  Perform the test as described in the *KODAK MIN-R Mammography Screen/Film Systems User Guide*, (KODAK Publication # M3-103, CAT No. 173 9473).
- *Uniformity of Screen Speed*
  Perform the test as described in the *KODAK MIN-R Mammography Screen/Film Systems User Guide)*, (KODAK Publication # M3-103, CAT No. 173 9473).

For More Information:

Outside U.S. please contact your local Kodak representative.

U.S. Distributors Contact:
Health Imaging
Technical Support
1-800-328-2910

CES Personnel Contact:
Film Handling TAC
U.S.: 1-800-328-2910

Canada: 1-800-433-1414

Kodak, MIN-R, and X-OMAT are trademarks.
© Eastman Kodak Company, 2003
Pub # M3-110
Cat # 891 9789

Tib3111 April 2002

TECHNICAL INFORMATION BULLETIN

Drains, Exhaust Venting, and Room Ventilation Requirements KODAK Medical Film Processors and Multiloaders

Updated April 2, 2002

Sources: Service Bulletins 101 (October 1992) and 180 (July 1993)

Drains

To avoid hazardous conditions, keep all floors, floor coverings, and associated drains around the processor clean and dry at all times. Any accumulation of fluids from mixing tanks, drain lines, etc., should be cleaned up immediately. In the event of any problem with the drain (accumulation of liquid due to backup, overflow, or other malfunction), call a plumber or other contractor. Kodak accepts no responsibility or liability for the serviceability of any drain connected to or associated with a Kodak medical film processor. Drains are the sole responsibility of the customer.

Important: Drains must be made of a chemically resistant, non-corrosive material (PVC or equivalent), must have a minimum diameter of 3 inches (7.6 cm), and must be free of obstructions. Copper drainage piping is not acceptable. Do not make a solid connection between the drain and the equipment.

Exhaust Venting

Background

Failure to properly vent the processor or multiloader exhaust can cause corrosion inside the equipment (and any interfaced equipment) and can increase the probability of film artifacts. Venting according to the specifications outlined in this bulletin will help minimize these problems.

Some equipment (like the KODAK X-OMAT 5000 RA Processor) may have different procedures and specifications for exhaust measurement. Service documentation for a particular piece of equipment always takes precedence over these recommendations.

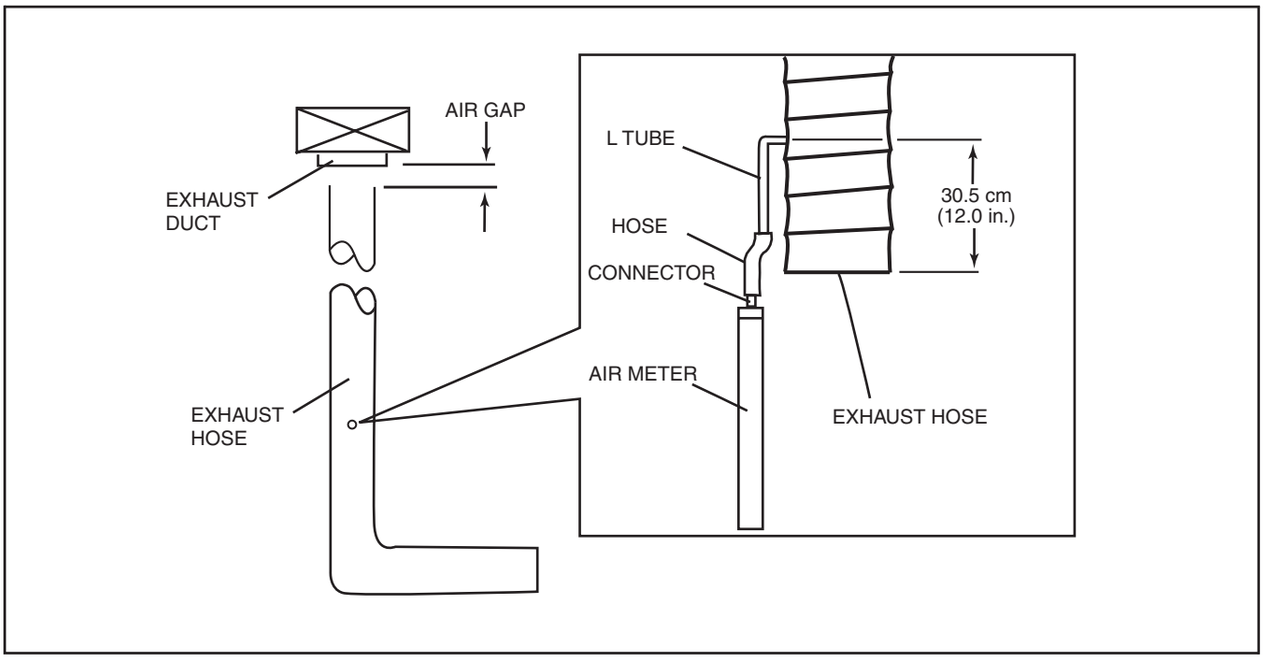
Items Needed

1. Air Meter (TL-2431).

   The above item can be ordered through Service Parts Management at 800-431-7278 (U.S.) or 585-724-6075 (Outside U.S.).

Procedure: Preparation

STEP	ACTION
1	Make sure the processor/multiloader exhaust hose is connected to the building exhaust system. Disposal of effluent air must comply with prevailing environmental codes.
2	*Power down the processor/multiloader.*
3	Disconnect the exhaust hose from the rear of the equipment.
4	Connect the rubber hose on the Air Meter's **center** connector.
5	Connect the L Tube to the rubber hose.
6	Make a 6.4 mm (1/4 in.) hole approximately 30.5 cm (12 in.) from the end of the exhaust hose that will be connected to the processor.
7	Insert the L Tube into the hole (Step 6) so the end of the L Tube is flush with the inside of the exhaust hose and perpendicular to the wall of the exhaust hose.
Important: Do not connect the exhaust hose to the processor when checking negative static pressure.	



Procedure: Measuring the Static Pressure

STEP	ACTION
1	Hold the air meter vertically to assure the greatest accuracy. Make sure the meter tubing is not kinked.
2	Record the average of several readings.
3	Compare the average reading with the information in the table below (Measuring the Static Pressure). **Important:** The negative airflow in the processor exhaust duct must remain constant when the processor is in the run, standby, and shut-down mode; therefore, the building exhaust system must be on 24 hours a day and have the same negative airflow throughout the day.
4	If the average reading is not within the tolerances specified in the table, adjust the Air Gap Assembly to obtain the tolerances. If the tolerances still cannot be obtained and you must exceed the maximum in order to obtain the correct negative static pressure, contact site management personnel to have the building exhaust corrected. **Important:** There must be an adequate air gap (maximum 5.08 cm / 2 inches) between the processor exhaust hose and the building exhaust to prevent positive airflow from flowing back into the processor. If the building exhaust venting system can not meet specifications, an Auxiliary Ventilation Fan Kit can be ordered through Service Parts Management.
5	Reconnect the exhaust hose to the processor.

Measuring the Static Pressure

Duct Diameter	Negative Static Pressure of Water Head	
	Minimum	Maximum
76 mm (3 in)	0.76 mm (0.03 in.)	1.02 mm (0.04 in.)
102 mm (4 in.)	0.25 mm (0.01 in.)	0.51 mm (0.o02 in.)

Additional Notes

If the processor/multiloader is installed in a darkroom wall opening, the darkroom air pressure *must exceed the air pressure of the area outside the darkroom*. This will:

- Prevent air from cascading through the processor and into the darkroom area.
- Assure correct dryer venting.
- Minimize chemical fume and vapor containment inside the processor and its dryer exhausting system.
- Reduce film artifacts in the out-of-solution transport roller sections.
- Reduce corrosion of the processor/multiloader.

Room Ventilation

The room must have a minimum of 10 air exchanges each hour.

NOTE: *Technical Information Bulletins provide information of limited or specific application. Responsibility for judging the applicability of the information for a specific use rests with the end user.*

Kodak and X-OMAT are trademarks of Eastman Kodak Company.

Ventilation and Work Practice Control Measures

Proper ventilation is important to assure a safe and comfortable indoor environment for photographic processing areas. Several common potential indoor air contaminants can be associated with photographic processing. These include: acetic acid, sulfur dioxide, and ammonia. These chemicals may be eye and respiratory tract irritants depending on their airborne concentrations. Exposure guidelines and standards for these chemicals have been established to prevent significant eye or respiratory tract irritation in most workers. Significant eye or respiratory tract irritation during normal photographic processing or maintenance operations may indicate elevated levels of these materials and the need for better control.

General control strategies in order of preference include:

- chemical substitution (where possible)
- engineering controls (ventilation, enclosures, process isolation)
- work practices or administrative controls (operating procedures, employee rotation)
- personal protective equipment (safety glasses, gloves, respirators)

Engineering controls that have proven to be effective in minimizing airborne levels of photographic processing chemicals include:

- Good design and layout for process flow and ergonomic considerations
- Using dilution and local exhaust ventilation
- Providing covers for processing equipment tanks and chemical storage tanks

Good Facility Design

The proper location and layout of photographic processing operations is an important element in designing a safe and healthy workplace.

General ventilation systems have the potential to recirculate a significant percentage of the air returning from the photographic processing areas. If the general ventilation system also supplies non-photographic processing work areas, it is possible that the photographic processing odors may also impact these areas.

Ventilation

Kodak studies of potential worker exposure during automated photographic processing operations have indicated that vapors and gases can be controlled to acceptable levels through good general room ventilation (dilution ventilation). However, in some cases, local exhaust for enclosed and/or open tanks may be recommended.

Dilution Ventilation

Dilution or general ventilation is simply bringing in and distributing enough fresh, uncontaminated air (preferably outdoor air) to dilute the indoor air contaminants to an acceptable level.

Minimum recommendations for general ventilation for buildings and processes are provided by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE).

For photographic processing operations, ASHRAE Standard 62-1989 recommends:

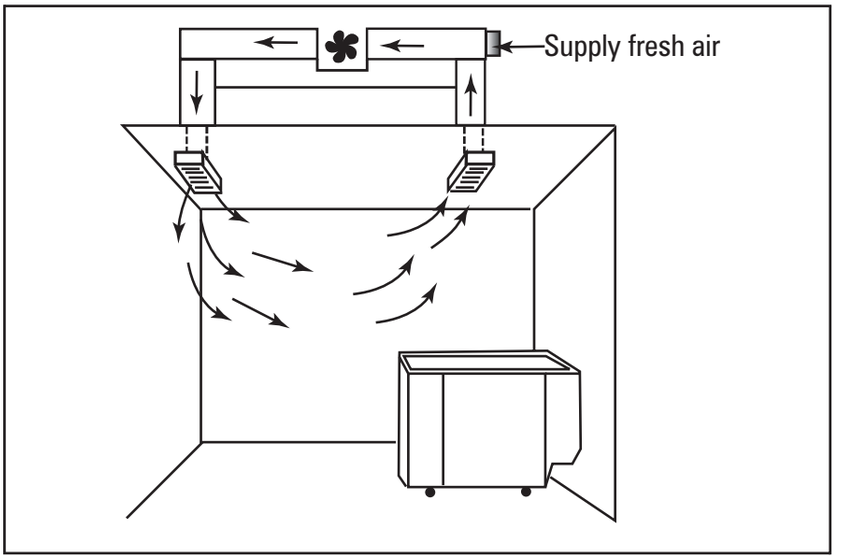
- 0.5 cubic feet per minute (cfm) of fresh outside air, per square foot (ft^2) of floor area (0.5 cfm/ft^2), assuming a maximum occupancy of 10 persons/1000 ft^2 in darkrooms.

For example, if the room where photoprocessing takes place is 10 ft x 20 ft x 8 ft, the floor area is 200 ft^2 and the room volume is 1600 ft^3 . Based on 0.5 cmf/ft^2 , you would need to supply at least 200 x 0.5 or 100 cfm of fresh outside air to the space.

The number of "room air changes per hour" is determined by the fresh air supply rate. In the example, in one hour 6000 ft^3 (100 ft^3 /min x 60 min) of fresh air entered the space (room volume: 1600 ft^3). To calculate the room air changes per hour, you divide the total amount of fresh air that has entered the space by the volume of the room: 6000 ft^3 /hr/1600 ft^3 room volume = 3.75 air changes per hour.

It is important to note that the ASHRAE recommendations represent the minimum amount of fresh air that should be supplied to the space. Past recommendations from Kodak have been as high as ten air changes per hour.

When using dilution ventilation, airborne contaminants are not captured at the source. Instead, the contaminated air is turned over and replaced quickly enough to minimize potential exposure and related odors. To be most effective, make sure you properly position the supply air inlets and return air outlets for good mixing/dilution of the room air. Their placement must minimize the potential for "short-circuiting" or direct flow of supply air to return with minimum room air mixing (Figure below). For a large room, you may need supply air inlets and return air outlets throughout the room. Do not position the inlet and outlets too close together.



Open tank processor with general room dilution ventilation

Local Exhaust Ventilation

Local exhaust ventilation is used to capture air contaminants close to the source of generation, before they can enter the general work room air. This type of ventilation can be very effective at controlling airborne contaminants. A general room exhaust system will reduce airborne levels but is not considered local exhaust ventilation. A local exhaust system may be more expensive to install than a general dilution ventilation system, but requires less air (and energy) to effectively control the airborne contaminants.

When designing local exhaust systems, the objective is to capture contaminants close to the source and draw the contaminated air stream away from the air you breathe. Avoid placing workstations between the source (photographic processor) and the inlet to the exhaust hood.

You can find information on the proper design of local exhaust systems in the ACGIH Industrial Ventilation Manual (ACGIH 1992).

The design must also consider the required "make-up" air system you'll need to replace and condition the air that is exhausted from the building. In addition, it is also important to review local laws and ordinances regarding local exhaust and any permit requirements with local, state, or federal regulators.

MQSA Equivalency Statement

November 2004

Re: KODAK X-ray films and intensifying screens for mammography
KODAK X-OMAT Developers, Fixer, Starter

The United States Food and Drug Administration (FDA) Mammography Quality Standards Act (MQSA) Final Regulations became effective April 28, 1999. The regulations require documentation on films and screens and processing chemicals used in mammography:

21 CFR 900.12(b)(11): *X-ray film. The facility shall use X-ray film for mammography that has been designated by the film manufacturer as appropriate for mammography.*

21 CFR 900.12(b)(12): *Intensifying screens. The facility shall use intensifying screens for mammography that have been designated by the screen manufacturer as appropriate for mammography and shall use film that is matched to the screen's spectral output as specified by the manufacturer.*

21 CFR 900.12 (b)(13): *For processing mammography films, the facility shall use chemical solutions that are capable of developing the films used by the facility in a manner equivalent to the minimum requirements specified by the film manufacturer.*

The FDA offers the following guidance in clarification of these rules:

- "Designated by the film manufacturer as appropriate for mammography" simply means that the film manufacturer has established that the properties of the film are appropriate for mammography and markets it for such purposes, not that the film must be sold only for mammography. One mechanism to establish compliance would be to have documentation from the manufacturer, such as advertising material or specific literature, that clearly identifies the film and its intended use.
- The facility is responsible for matching the sensitivity of the film with the spectral output of the screen. Examples of acceptable methods to establish compliance would be to provide documentation from the screen and/or film manufacturer, such as advertising material or specific literature, that clearly identifies the appropriateness of the combination or specifies the screen output and the film sensitivity showing a match between them. Otherwise, the facility should independently show that matching has been established.
- The "facility must either have documentation from the chemical manufacturer/ supplier or the film manufacturer showing that the processing chemicals being used provide results consistent with the film manufacturer's processing specifications, or the facility must establish that the film performance is sensitometrically equivalent to films developed according to the film manufacturer's specific recommendations."

As the manufacturer, Eastman Kodak Co. certifies the following:

These films are appropriate and marketed for use in mammography with green emitting intensifying screens:

- MIN-R EV
- MIN-R 2000
- MIN-R L

These intensifying screens are appropriate, and marketed, for use in mammography. They are composed of terbium activated gadolinium oxysulfide with primary emission in the green spectral region.

- KODAK MIN-R EV 150
- KODAK MIN-R EV 190
- MIN-R 2000
- MIN-R 2190
- MIN-R

In addition, Eastman Kodak Company certifies that any of the above films are spectrally matched to any of the above intensifying screens. The MIN-R EV 150 and MIN-R EV 190 screens are specially designed to work with KODAK MIN-R EV Film.

Although they have been specifically designed to produce optimal results in the above combinations, the above listed films would be spectrally matched with other commercial intensifying screens that are composed of terbium activated gadolinium oxysulfide, as these will have similar emission spectra and should provide acceptable results. Similarly, the above listed intensifying screens would be spectrally matched to films from other manufacturers that require green emission. Speed/ dose of the systems could be different.

Eastman Kodak Company recommends the use of KODAK X-OMAT EX II Developer and Replenisher, KODAK RP X-OMAT Developer and Replenisher, KODAK RP X-OMAT LO Fixer and Replenisher and KODAK RP X-OMAT Developer Starter, for optimal results with the KODAK Mammography films listed above. We do not recommend the use of KODAK Medical X-Ray Developer and Replenisher for use with KODAK mammography films due to the sensitometric and/or viewbox appearance of the film. Acceptable results are expected with the use of KODAK Medical X-Ray Fixer and Replenisher. It is important to follow Kodak's mixing and processing recommendations.

Acceptable results with mammography film from some other manufacturers are expected with the use of these KODAK chemical solutions.

Eastman Kodak Company does not recommend the use of SOURCE ONE 3-7-90 M, 3-7-90 S, Mammo-Plus, Envirocare RP-LO or Spectra Developer and Envirocare RP-LO or Spectra Fixer, WHITE MOUNTAIN T-2 EX, WHITE MOUNTAIN T2 MR or WHITE MOUNTAIN T-2 Developers and WHITE MOUNTAIN T-2 Fixer, ALLIED AUTEX A2 HC PLUS or ALLIED AUTEX SE or ALLIED AUTEX RP Developers and AUTEX RP or AUTEX CLASSIC Fixer, HR SIMON Chemblend 2 Developer and Fixer and AGFA HD Developer and AGFA GP Fixer with KODAK mammography films. Use of these developer and fixer combinations may adversely affect the sensitometric and/or viewbox appearance of the film.

Procedures for verifying adequate processing of KODAK Mammography Films with other developers and fixers are available from Kodak via the Kodak website at http://www.kodak.com/go/mammo.

Note: KODAK, X-OMAT and MIN-R are trademarks of Eastman Kodak Company.

Forms

Speed Uniformity Data Sheet

Site / x-ray unit _____ Processor Used _____

Screen type _____

Film type _____

Emulsion No. _____

AEC setting _____

KVp _____

MA/mAs setting _____

*Enter the data in test order, making sure that the control is run at the start, middle and end of the test. Large and small cassettes should be tested separately.

Control Cassette ID _____ **Size** _____

	Cassette ID	Actual mAs	Density
Control Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Control Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Test Cassette			
Control Cassette			

Average of controls	
Standard deviation of controls	
Range of all cassettes	

© Eastman Kodak Company, 1999

References

1. *Chemistry Matters,* by Alan Fitterman, 2001, CAT No. 887 3911.
2. K*odak Processing Chemicals Optimization Guide,* 2001, CAT no. 149 1109.
3. *KODAK MIN-R 2000 Film System User Guide,* 2002, CAT no. 193 9826.
4. Artifacts in Screen-Film Mammography CD-Rom.
5. P. Bunch, *"The effects of reduced film granularity on mammographic image quality,"* SPIE, 3032, pp. 302-307, 1997.
6. P. Bunch, *"Advances in high-speed mammographic image quality,"* SPIE, 3659, 1999.
7. Hendrick, R.E. and Berns, E.A. *Optimizing the Selection of Film and Film Processing. In: Advances in Film Processing Systems Technology and Quality Control in Medical Imaging,* edited by Arthur G. Haus (Medical Physics Publishing, Madison, WI, 2001), 115-127.
8. Hendrick, R.E. and Berns, E.A. *Optimizing Mammographic Techniques. In: 1999 Syllabus Categorical Course in Diagnostic Radiology Physics: Physical Aspects of Breast Imaging – Current and Future Considerations,* edited by A.G. Haus and M.J. Yaffe (Radiologic Society of North America Publishing, Oak Brook, IL, 1999) 79-89.
9. Hendrick, R.E. and Berns, E.A. *Optimizing Techniques in Screen-Film Mammography. In: Radiologic Clinics of North America* Vol 38 No. 4:701-718, July 2000.
10. *Mammography Quality Control Manual for Radiologists, Medical Physicists and Technologists.* Reston, VA: American College of Radiology, 1999.
11. *Recommended Specifications for New Mammography Equipment: Screen-Film x-Ray Systems, Image Receptors, and Film Processors.* Reston, VA: American College of Radiology, 1995.
12. *Processing Recommendations for KODAK X-OMAT and MIN-R Processors* (September 2001 revision), Publication N-923 (See Appendix)
13. *Conversion Instructions and Processing Recommendations for KODAK MIN-R EV Film,* Publication M3-110. (See Appendix)
14. KODAK Service Bulletin No. 101. Drying Venting Requirements for all KODAK X-OMAT Processors. (See Appendix)
15. *Indoor Air Quality and Ventilation in Photographic Processing Facilities,* Publication J-14.
16. Moore, William E., Dickerson, Robert, Steklenski, David, *"Design and performance features of a new mammographic film/screen system"* Paper number 54 Proc. SPIE, 5368, 2004.
17. Cardenosa, Gilda. *Breast Imaging Companion.* 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2001.
18. Feig, MD, Stephen A., ed. *The Radiologic Clinics of North America Breast Imaging.* Vol. 38:4 Philadelphia: W.B. Saunders Co., 2000.
19. Cardenosa, Gilda. "Image Quality in Breast Imaging." *Seminars in Breast Disease* 2.1 (1999): 17-20.
20. Vyborny, Carl J., and Arthur G. Haus. "Signal Detection, Image Quality, and Radiation Dose in Mammography." *Seminars in Breast Disease* June 2003: 58-66.
21. Gabbay, Emile . "Mammography X-ray Source." *Syllabus: A Categorical Course in Phyics: Technical Aspects of Breast Imaging.* Ed. Arthur G. Haus, and Martin J. Yaffee, Phd. Oak Brook: RSNA Radiological Society of North America, 1994. 47-62.
22. Yaffe, Martin J., Jennings, Robert J., Fahrig, Rebecca, Fewell, Thomas R. "X-Ray Spectral Considerations for Mammography." *Syllabus: A Categorical Course in Phyics: Technical Aspects of Breast Imaging.* Ed. Arthur G. Haus, and Martin J. Yaffee, Phd. Oak Brook: RSNA Radiological Society of North America, 1994. 63-73.
23. Rothenberg, Lawrence N. "Exposures and Doses in Mammography." *Syllabus: A Categorical Course in Physics: Technical Aspects of Breast Imaging.* Ed. Arthur G. Haus, and Martin J. Yaffee, Phd. Oak Brook: RSNA Radiological Society of North America, 1994. 113-119.

www.kodak.com/go/medical

Health Group
EASTMAN KODAK COMPANY
343 State Street
Rochester, NY 14650-1132
1-800-328-2910

KODAK CANADA INC.
3500 Eglinton Avenue West
Toronto, Ontario M6M 1V3
CANADA

Outside the U.S. or Canada, please contact your local Kodak company.

Kodak, Min-R, T-Grain, and X-Omat are trademarks of Eastman Kodak Company.
M3-103 Printed in U.S.A. 2/06 ©Eastman Kodak Company, 2006 CAT No. 173 9473